THE GEOLOGY OF THE CAIRNSMORE OF FLEET GRANITE AND ITS ENVIRONS, SOUTHWEST SCOTLAND

VOLUME 2

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VOLUME 2

APPENDICES, TABLES, FIGURES, PLATES AND MAPS.

APPENDIX 1

Sample preparation and methods of chemical analysis of silicates and sulphides, and staining of carbonates.

A. SAMPLE PREPARATION

(i) Sample collection

Samples of granite, greywacke and hornfels have been collected on the basis of a staggered 1 km grid (using National Grid intersections) where possible, effectively each sample locality is approximately 1.5 km from the next (Fig. 2). Care was taken to ensure that samples were from unweathered material. Mineralized material was collected where possible from veins *in situ*, however in most cases samples from spoil tips at mines and trial workings had to be used.

(ii) Crushing

Samples of intrusive and sedimentary rocks were reduced in size using a Cutrock hydraulic rock splitter and any remaining weathered surfaces were ground away on a diamond wheel. Suitable sized fragments were coarsely crushed in a Sturtevant jaw crusher. For each sample at least 1 kg of granitic material and 0.5 kg of country rock was crushed. All material from the jaw crusher was reduced to approximately 100 mesh in a Tema tungsten carbide laboratory disc mill. The resulting powder was mixed thoroughly and reduced in size by quartering. Opposing quarters of the coned sample were crushed further in the disc mill until the powder was approximately 200 mesh. Every precaution was taken throughout the procedure to keep dust loss to a minimum and to ensure that the final powdered sample was representative of the original rock. The ca. 200 mesh material was used for chemical analysis and the ca. 100 mesh material retained for mineral separation.

All separated sulphide and silicate minerals were crushed by hand with an agate mortar and pestle, owing to small sample size.

(iii) Mineral separation

For separation of granitic minerals the ca. 100 mesh powder from the procedure above was sieved into three size fractions; -140 + 200 mesh, -100 + 140 mesh and -80 + 100 mesh. Each fraction was washed three times in distilled water, the supernatent carrying dust particles was decanted carefully each time to avoid loss of micaceous minerals. The washed material was filtered through Whatmans No. 40 filter paper and dried in an oven at 105°C. Prior to separation on the Franz isodynamic separator samples were passed down a glazed paper chute between the poles of a very strong horseshoe magnet to remove ferromagnetic minerals, such as magnetite. In order to obtain good separation each size fraction was treated independantly on the isodynamic separator under the conditions outlined below:

Stage	amps.	$s.s^o$	$f.s^o$	magnetic	non-magnetic
1	0.40	20	25	biotite, chlorite, garnet, ilmenite.	muscovite, quartz, feld-spar.
2	0.35	20	20	chlorite, ilmenite, garnet.	biotite, garnet
3	1.00	20	20	biotite aggregates.	muscovite, quartz, feld-spar
4	1.10	20	25	muscovite	quartz, feld-spar.
5	1.40	5	25	muscovite aggregates.	quartz, feld-spar.

Amperage settings shown in the table above varied slightly with each sample, depending upon the composition of the micas ($s.s^o$ = side slope angle; $f.s^o$ = forward slope angle).

After minerals had been separated in stage 1 (above) the magnetic fraction was reseparated in stage 2. The garnet in sample 73/G 57-69 could not be separated completely by this method and was subsequently separated from biotite and chlorite using heavy liquid separation (bromoform, S.G. = 2.90). When there was no ilmenite present pure chlorite was obtained after stage 2 and if there was an adequate amount this was analysed chemically (see below). Pure biotite was also obtained after stage 2 as the magnetic fraction.

The non-magnetic fraction after stage 1 was processed under the conditions of stage 3 which removed all biotite-feldspar and biotite-quartz aggregates. The non-magnetic fraction so produced was passed through the separator in stage 4, after which a pure fraction of muscovite was obtained. The remaining material was 'cleaned' of muscovite-quartz and muscovite-feldspar aggregates in stage 6, leaving a felsic mineral fraction.

Ore minerals were separated by hand after suitable samples of vein material had been coarsely crushed with a tungsten carbide mortar and pestle. The resulting material was sieved and 14 mesh and -14 + 18 mesh fractions obtained. Ore minerals were hand picked using tweezers under a binocular microscope, and were subsequently washed in propanone (acetone).

B. CHEMICAL ANALYSIS

Detailed accounts of the analytical procedures are provided in a number of publications and will therefore only be summarized.

(i) Major element analysis of silicate rocks and minerals.

Major element analysis by atomic absorption spectrophotometry is an adaptation of a number of methods, all of which are outlined in Batchelor (1975a). Rock powders are fused with lithium metaborate and the resulting bead dissolved in dilute nitric acid. The solution is diluted to volume with distilled water after addition of La^{3+} ions to overcome interference in the determination of alkaline earth elements. The solutions thus obtained are aspirated directly into a Varian Techron (A.A. 4) atomic absorption spectrophotometer under specified conditions

(Batchelor, 1975c), and compared with mixed artificially prepared standard solutions. Accuracy, reproducability and comparison with international standards of the results obtained are tabulated in tables 22 and 23.

(ii) Minor and trace element analysis of silicate rocks and minerals.

The silicates are decomposed with hydrofluoric and perchloric acids at room temperature (Batchelor, 1975a), the acids are fumed off and the resulting crystals dissolved in distilled water. Solutions obtained in this way are analysed by atomic absorption spectrophotometry (tables 22 and 23).

(iii) Determination of FeO, P_2O_5, H_2O^-, H_2O^+ and loss on ignition.

Detailed description of the methods of analysis are provided in Batchelor (1975b).

FeO is determined after decomposition of the rock powder with hydrofluoric acid at room temperature in the presence of a known quantity of V^{5+} ions. Boric acid and phosphoric acid are added to complex HF and Fe^{3+} respectively The solution is titrated against standard dichromate solution after addition of excess Fe^{2+} salt.

P_2O_5 is determined colorimetrically on a Unicam SP 600 spectrophotometer as a phosphomolybdate complex using the solution prepared for trace element analysis above (ii).

The analysis of H_2O^- requires heating the powdered sample in an oven at 105°C for a number of hours until weight loss is negligible. Total water (H_2Ot) is determined by heating the powdered sample in an ignition tube and collecting the water driven off in filter paper at the cooled upper end of the tube. H_2O^- is subtracted from H_2Ot to give the H_2O^+ value.

The sample is heated in a platinum basin at ca. 1000^oC for a number of hours in order to analyse for loss on ignition. The results given in appendix 3 have been adjusted for weight increase due to the Fe^{2+}--- Fe^{3+} conversion and H_2Ot.

(iv) X-ray fluorescence analysis of Rb, Sr, Y, Zr, Cu, Pb, Zn.

In rocks and minerals with low amounts (100 ppm) Cu, Pb and Zn. XRF analysis was used in preference to atomic absorption. Samples for X-ray analysis are pelletized in a boat of boric acid crystals produced at 2000 lb per sq. inch, and compressed under a 20 ton load in evacuated conditions. Analysis is undertaken using a Phillips PW 1540 generator unit, tungsten tube, LiF 200 analysing crystal and a PW 1964/20 scintillation probe. Compressed samples are counted for 100 secs. under conditions described in the University of St. Andrews, Department of Geology, X-ray users guide.

Results are computed using an estimate of the total mass absorption coefficient (TMAC) assuming the ratio of the backgrounds of the sample and standard are equal to the ratio of the sample TMAC to the standard TMAC; this is valid if the standard and sample are of similar composition. For this reason U.S.G.S. standards G-2 and GSP-1 were used in the granite and country rock analyses respectively.

(v) Energy dispersive analysis of Ba, La, Ce, Nd

In this technique a primary γ ray (26.35 Kev) source of 300 m Ci ^{241}Am sealed in a stainless steel capsule is used. The energy dispersive analyser is a Nuclear Enterprises Ge (Li) detector type GDX 25-3A with associated amplifiers, etc., linked to a Laben 100 C, 100 channel pulse height analyser. Powdered samples are counted for 2000 secs. and the 100 channel spectrum output automatically punched onto computer paper tape. An internal standard 73/G 55-75 was calibrated using U.S.G.S. standards G-2, GSP-1, AGV-1 and BCR-1. Lines used are Ba$K\alpha'$ (32.19 Kev), La $K\alpha'$ (33.44 Kev), Ce $K\alpha'$ (34.72 Kev) and Nd $K\alpha'$ (37.36 Kev). A mass absorption correction was employed when computing the results. The whole technique has been described in detail by Stephens and Fowler (1973), where lower limits of detection for Ba, La, Ce, and Nd are quoted as 7, 13, 6 and 9 ppm respectively.

(vi) Sulphide analysis

Three methods are used to analyse separated sulphide minerals and crude ores and all employ atomic absorption spectrophotometry (Batchelor 1976b, 1976c). Cu, Pb, Zn, Ni, Co, Cr, Cd, Fe and Mn are determined in solutions derived from a hydrochloric and nitric acid attack on powdered samples. The element As due to the volability of its trivalent chloride cannot be analysed using the above dissolution, therefore a highly oxidizing nitric acid attack is employed. The method of Ag analysis relies on the high solubility of Ag salts in ammonia solution. A mixed hydrochloric, nitric and perchloric acid digestion of the sulphide is followed, after fuming much of the acid off, by addition of ammonia solution to precipitate insoluble hydroxides. The resulting solution is filtered and aspirated into the atomic absorption spectrophotometer, and absorbances are compared with mixed synthetic standard solutions (table 24).

(vii) Staining techniques for carbonate minerals

Slabs and thin sections of gangue carbonates are stained by the method of Dickson (1965) described in Batchelor (1976a). Calcite, ferroan calcite, dolomite and ferroan dolomite may be distinguished using acidified solutions of potassium ferricyanide and alizarin red S.

N.B. On the analysis sheets, - indicates the value is below the limit of detection for the analysis and n.d. signifies that the element was not determined. Figures to two or one decimal places are weight percentages and integers are parts per million.

APPENDIX 2

Techniques of statistical analysis.

(i) Correlation and regression analysis

A computer program was used to plot scatter diagrams of two variables and to calculate regression and correlation parameters. Linear regression in this technique is calculated by a standard least squares analysis, and its significance determined using the F test at appropriate degrees of freedom. Correlation is indicated by the product moment correlation coefficient (r), the significance of which was tested using tabulated values of r at given significance. Correlations of variables greater than 97.5% significance are shown in the matrices appropriate to each section (Figs. 4-8, 75-78). Linear regression lines on the scatter diagrams (Figs. 10-14, 79-83) have a significance greater than 95% for correlations with a significance greater than 97.5%.

(ii) Trend surface analysis

Trend surface analysis was undertaken using a program devised by W.E. Stephens (ESMAP). Polynomial trend surfaces are produced in this technique by the least squares regression method as described by Davis (1973). Contour maps are generated of the trend surface and residual data (Figs. 35, 51, 52, 54-56, 58-61, 63-68, 70-74). Also included in the program is a contouring method involving a simple interpolation technique (Davis, 1973) using four nearest data points and transposition of this information onto a regular grid. Interpolation is effected by Pythagorian distance weighting. The 50 x 50 grid is contoured using the method of Cole (1969) (Figs. 35, 51-74). Best fit trend surfaces produced by this method are selected by using the F test on progressive polynomial surfaces. The contour interval is half the standard deviation (s) on contour and trend surface maps and equals the standard deviation (s) on residual maps.

(iii) Cluster analysis

A computer program, CLUSTAN 1A (author, D. Wishart) which is an adaptation of CLUSTAN 1 (Wishart, 1969) was used for this analysis, which is basically two a stage process. Firstly an estimation is made of the dissimilarity of all possible combinations of samples using the Euclidean distance coefficient:

$$d_{ij} = \frac{1}{M} \sum_{k=1}^{m} \left\{ x_{ik} - x_{jk} \right\}^2$$

A matrix of these coefficients is then generated. The second or fusion stage is effected by Ward's error sum method, by which fusion takes place at each stage between sample with sample, sample with cluster and cluster with cluster, which gives rise to the smallest increase in variance. Output consists of a listing of the means and standard deviations of data in various clusters (tables 2-4, 11, 12 and 15A) and a dendrogram showing the similarity between samples and clusters (Figs. 3, 41, and 100). Significance of each cluster is difficult to test, but selection has been made at the number of clusters at which fusion of another cluster brings about a larger than normal increase in fusion coefficient (see insert graphs on Figs. 3 and 41), following Dawson and Stephens (1975). The reader is referred to the above work for an account of the application of cluster analysis to geochemical data.

APPENDIX 3.

Chemical analyses of the sedimentary rock samples

All sedimentary rock sample numbers have the prefix 74/H.-----, e.g. 74/H. 44-66, but for clarity this is not included in the numbers on the lists of analyses.

L. Lithic group greywacke.

B. Basic group greywacke.

F. Feldspathic group greywacke.

S. Silicic group greywacke.

Sh. Shale.

C. Contaminated sample.

Major elements are in weight percent and trace elements in parts per million.

	44-66	44-68	45-65	45-67	45-69	45-71
	L	L	L	L	B	B
SiO_2	67.63	65.56	64.06	64.94	66.05	66.61
TiO_2	0.65	0.71	0.79	0.90	0.74	0.33
Al_2O_3	9.95	11.68	13.21	12.30	12.43	11.81
Fe_2O_3	0.27	-	0.24	0.94	0.33	0.67
FeO	3.81	5.89	5.04	4.59	5.10	4.63
MnO	0.07	0.07	0.12	0.11	0.09	0.07
MgO	3.32	4.20	5.07	3.71	5.05	4.40
CaO	4.14	2.12	5.65	2.91	1.55	2.10
Na_2O	2.14	2.56	2.07	2.70	3.53	2.61
K_2O	1.83	1.79	1.44	2.31	1.04	1.54
P_2O_5	0.16	0.16	0.18	0.27	0.14	0.13
H_2O^+	1.75	2.80	0.65	2.07	2.36	2.05
H_2O^-	0.13	0.12	0.13	0.31	0.15	0.10
LOI	3.15	1.28	0.96	1.41	1.47	3.43
Total	99.00	98.94	99.61	99.47	100.03	100.48
Li	57	74	59	98	72	74
Rb	51	43	53	75	36	61
Be	3	3	-	-	1	3
Sr	228	188	287	353	205	183
Y	12	14	17	21	10	13
Zr	277	288	216	372	224	202
Cr	215	176	175	224	331	300
Ni	78	67	92	51	144	112
Cu	24	22	23	30	28	28
Zn	52	62	67	75	52	64
Pb	23	23	21	21	27	25

	46-64	46-66	46-68	46-70	47-61	47-63
	F	B	L	Sh	L	L
SiO_2	59.70	67.91	70.48	56.61	65.56	61.51
TiO_2	0.67	0.82	0.72	0.87	0.53	0.68
Al_2O_3	17.30	11.20	11.43	17.39	12.71	14.23
Fe_2O_3	0.42	0.01	0.27	2.63	0.43	-
FeO	4.53	5.47	4.28	5.43	3.92	5.23
MnO	0.09	0.07	0.09	0.17	0.07	0.09
MgO	3.09	4.76	3.63	6.82	3.38	4.16
CaO	4.87	2.20	1.13	2.41	3.82	3.99
Na_2O	4.22	1.89	2.47	1.88	2.47	2.60
K_2O	2.80	1.93	1.43	2.80	2.46	2.39
P_2O_5	0.23	0.17	0.20	0.08	0.16	0.25
H_2O^+	0.43	2.40	1.75	2.96	0.91	2.12
H_2O^-	0.19	0.33	0.32	0.12	0.13	0.20
LOI	0.75	1.64	0.83	0.87	2.78	2.69
Total	99.29	101.08	99.21	101.04	99.33	100.15
Li	60	201	90	136	68	170
Rb	83	70	52	119	91	81
Be	1	2	2	4	1	2
Sr	632	245	283	286	286	354
Y	11	18	16	20	16	21
Zr	190	330	296	188	228	263
Cr	8	356	236	288	168	112
Ni	40	75	89	174	105	67
Cu	24	29	26	33	26	27
Zn	70	63	55	102	95	77
Pb	31	21	24	30	32	26

	47-65	47-67	47-69	47-71	47-73	48-58
	B	B	L	Sh	C	S
SiO_2	73.63	72.02	69.59	61.87	55.26	71.57
TiO_2	0.61	0.61	0.78	0.72	0.49	0.46
Al_2O_3	10.22	10.43	11.74	16.31	18.46	8.72
Fe_2O_3	0.17	0.11	0.32	-	0.59	0.38
FeO	3.57	3.95	4.34	7.09	7.72	3.06
MnO	0.09	0.06	0.07	0.08	0.08	0.06
MgO	3.68	4.07	3.85	4.91	7.06	2.54
CaO	3.65	1.14	2.24	0.52	0.22	3.50
Na_2O	0.60	1.72	2.67	1.35	1.59	1.90
K_2O	1.44	2.62	2.41	3.44	3.29	1.17
P_2O_5	0.19	0.13	0.20	0.15	0.16	0.09
H_2O^+	0.80	1.95	0.69	3.19	4.18	0.78
H_2O^-	0.21	0.19	0.15	0.20	0.40	0.15
LOI	1.97	0.87	0.70	1.26	1.19	4.31
Total	100.83	99.94	99.75	101.09	100.69	98.69
Li	108	152	96	126	137	49
Rb	110	100	82	134	135	47
Be	4	-	-	1	5	1
Sr	234	263	305	83	53	115
Y	17	16	18	17	21	14
Zr	282	306	272	186	167	193
Cr	198	256	178	163	284	98
Ni	65	77	68	79	213	38
Cu	28	26	24	29	37	25
Zn	35	52	61	93	569	44
Pb	20	16	29	31	228	26

	48-62	48-64	48-66	48-68	48-70	48-72
	L	Sh	Sh	B	B	Sh
SiO_2	66.26	63.97	65.96	72.95	70.58	56.82
TiO_2	0.81	0.74	0.64	0.74	0.73	0.75
Al_2O_3	12.59	15.09	14.65	9.83	9.91	16.88
Fe_2O_3	0.47	0.43	0.58	-	-	0.79
FeO	4.55	6.20	5.56	3.82	4.80	7.53
MnO	0.11	0.35	0.21	0.07	0.08	0.11
MgO	3.70	4.54	4.19	3.37	4.25	6.48
CaO	3.64	1.25	0.91	1.94	3.24	1.97
Na_2O	2.51	1.17	1.55	0.48	1.59	2.17
K_2O	3.08	3.80	3.27	2.83	2.46	3.23
P_2O_5	0.20	0.08	0.09	0.11	0.13	0.13
H_2O^+	0.79	1.76	1.69	0.80	1.10	2.21
H_2O^-	0.11	0.14	0.24	0.14	0.07	0.19
LOI	2.14	0.87	1.10	1.05	0.82	1.14
Total	100.96	100.39	100.64	98.13	99.76	100.40
Li	97	99	156	173	160	223
Rb	90	145	136	111	97	132
Be	3	4	1	2	-	1
Sr	478	144	97	171	198	186
Y	20	22	22	15	17	22
Zr	421	171	166	355	300	170
Cr	373	226	161	456	406	209
Ni	90	129	99	72	106	149
Cu	28	28	33	27	29	31
Zn	59	99	86	52	57	113
Pb	31	29	34	23	24	31

	48-74	49-59	49-61	49-73	49-75	50-58
	S	S	L	B	S	S
SiO_2	78.23	70.43	67.10	70.23	74.93	71.48
TiO_2	0.50	0.47	0.61	0.62	0.52	0.46
Al_2O_3	7.74	10.27	13.50	10.48	9.50	9.55
Fe_2O_3	-	0.30	0.48	0.17	0.09	0.61
FeO	3.12	4.14	3.94	4.38	3.82	3.03
MnO	0.05	0.07	0.07	0.06	0.05	0.06
MgO	1.80	3.71	3.11	4.07	2.15	4.06
CaO	1.67	3.39	2.66	2.37	1.03	2.78
Na_2O	2.12	2.10	1.96	2.45	2.23	1.32
K_2O	0.80	1.22	3.28	1.90	1.35	1.81
P_2O_5	0.16	0.10	0.16	0.10	0.17	0.09
H_2O^+	1.02	1.51	0.88	0.90	1.52	1.59
H_2O^-	0.24	0.12	0.24	0.10	0.24	0.17
LOI	1.80	2.68	1.71	1.44	1.22	4.55
Total	99.25	100.51	99.70	99.27	98.82	101.56
Li	43	71	75	87	56	66
Rb	28	61	103	48	54	56
Be	2	-	-	3	3	1
Sr	102	130	302	205	91	39
Y	12	16	16	10	15	14
Zr	336	207	250	192	251	191
Cr	72	134	124	351	77	95
Ni	18	53	70	83	36	41
Cu	23	28	25	27	25	20
Zn	41	60	55	53	57	40
Pb	18	26	16	23	22	12

	50-60	50-62	50-64	50-74	50-76	51-59
	S	F	L	B	S	S
SiO_2	73.20	67.96	67.64	66.06	69.62	58.88
TiO_2	0.56	0.65	0.88	0.89	0.57	0.35
Al_2O_3	9.76	13.78	11.86	11.78	11.11	9.63
Fe_2O_3	0.78	0.97	0.75	0.55	0.31	0.73
FeO	3.29	3.39	4.92	5.29	4.41	3.70
MnO	0.09	0.10	0.10	0.11	0.07	0.09
MgO	2.85	2.93	3.85	5.37	2.88	4.79
CaO	5.87	5.04	2.65	2.87	2.32	8.41
Na_2O	1.69	2.59	2.81	2.42	1.97	1.29
K_2O	0.44	1.98	1.84	1.21	1.76	1.97
P_2O_5	0.10	0.16	0.18	0.13	0.18	0.14
H_2O^+	0.52	0.45	0.73	2.37	2.01	1.81
H_2O^-	0.07	0.20	0.16	0.18	0.22	0.24
LOI	1.06	1.50	0.57	1.94	2.31	7.39
Total	100.28	101.70	98.93	101.17	99.74	99.42
Li	35	62	57	139	71	61
Rb	14	71	68	35	74	95
Be	2	2	2	1	1	4
Sr	241	550	434	201	133	275
Y	12	14	13	14	18	16
Zr	239	261	355	252	271	183
Cr	96	130	259	566	113	137
Ni	45	69	116	118	42	59
Cu	32	25	23	27	27	24
Zn	36	54	60	60	69	56
Pb	30	28	30	24	26	27

	51-61	51-63	51-75	52-60	52-62	52-76
	B	L	B	L	F	B
SiO_2	72.77	70.10	67.93	69.38	67.60	68.55
TiO_2	0.67	0.58	0.62	0.69	0.64	0.73
Al_2O_3	9.91	12.22	12.10	12.05	14.46	11.04
Fe_2O_3	0.54	0.25	0.20	0.45	0.50	0.07
FeO	3.72	3.90	4.48	4.92	3.75	5.00
MnO	0.06	0.06	0.07	0.05	0.09	0.07
MgO	2.87	3.17	4.50	4.48	3.07	4.68
CaO	2.52	1.74	2.28	1.10	3.08	1.51
Na_2O	1.97	2.56	3.12	1.45	3.31	2.14
K_2O	1.64	2.40	0.91	2.40	2.51	1.53
P_2O_5	0.11	0.14	0.14	0.12	0.20	0.12
H_2O^+	0.72	0.54	2.20	1.81	0.62	2.00
H_2O^-	0.13	0.25	0.15	0.17	0.15	0.16
LOI	1.24	0.94	1.30	1.01	1.25	1.50
Total	98.87	98.85	100.00	100.08	101.23	99.10
Li	77	82	186	96	69	67
Rb	76	92	39	110	85	51
Be	2	-	4	-	2	-
Sr	172	243	294	119	529	139
Y	19	15	11	22	15	10
Zr	328	301	247	257	256	188
Cr	159	189	232	140	153	375
Ni	54	93	84	68	70	111
Cu	26	27	25	27	23	24
Zn	54	52	55	72	57	70
Pb	22	23	20	25	30	17

	53-59	53-61	53-63	53-75	53-77	54-60
	Sh	B	L	S	B	L
SiO_2	52.22	75.18	68.45	76.46	64.42	69.51
TiO_2	0.58	0.70	0.71	0.44	0.78	0.56
Al_2O_3	13.21	8.45	13.77	8.80	10.87	13.84
Fe_2O_3	0.09	-	-	0.19	0.31	0.84
FeO	5.23	4.11	5.08	3.26	5.35	4.08
MnO	0.10	0.06	0.08	0.06	0.08	0.04
MgO	6.20	2.40	4.37	1.81	5.19	3.37
CaO	6.32	3.50	1.71	1.16	3.20	0.26
Na_2O	1.78	1.45	2.17	2.25	2.12	2.03
K_2O	2.22	1.82	2.84	1.08	1.54	2.38
P_2O_5	0.17	0.10	0.17	0.13	0.13	0.13
H_2O^+	2.04	0.66	1.09	1.25	2.60	2.31
H_2O^-	0.20	0.09	0.19	0.26	0.16	0.23
LOI	9.36	2.32	0.86	1.36	2.87	0.64
Total	100.53	100.84	101.49	98.51	99.62	100.22
Li	95	63	68	48	91	81
Rb	97	80	108	42	51	90
Be	3	2	-	-	3	4
Sr	164	169	260	90	159	73
Y	18	18	19	12	14	20
Zr	166	396	276	279	233	296
Cr	155	237	179	63	289	116
Ni	90	49	111	38	116	50
Cu	29	25	25	23	28	27
Zn	87	50	62	50	67	69
Pb	31	20	29	15	20	25

	54-62	54-76	55-61	55-63	55-77	56-62
	F	F	L	L	L	Sh
SiO_2	69.41	59.44	66.58	62.71	69.55	57.95
TiO_2	0.64	0.85	0.67	0.62	0.68	0.83
Al_2O_3	13.71	14.60	13.24	15.08	10.90	19.10
Fe_2O_3	0.44	0.55	0.71	0.52	0.58	0.91
FeO	3.83	5.84	5.08	5.28	4.24	6.03
MnO	0.06	0.09	0.06	0.09	0.07	0.10
MgO	2.85	6.15	3.91	4.32	3.80	3.87
CaO	1.77	2.24	0.45	2.23	1.46	1.06
Na_2O	4.31	4.04	2.42	2.50	2.43	1.26
K_2O	1.23	1.72	1.81	2.98	2.18	5.44
P_2O_5	0.19	0.20	0.13	0.17	0.16	0.12
H_2O^+	0.77	2.12	2.30	1.58	2.10	1.84
H_2O^-	0.27	0.22	0.07	0.26	0.16	0.18
LOI	0.64	1.36	1.19	0.26	1.08	0.99
Total	100.12	99.42	98.62	98.60	99.39	99.68
Li	94	83	97	152	89	158
Rb	58	45	82	124	68	201
Be	-	4	2	4	3	2
Sr	582	496	73	371	270	288
Y	13	11	20	20	15	26
Zr	311	245	257	225	289	235
Cr	88	262	138	124	228	148
Ni	69	102	72	73	84	84
Cu	26	29	29	28	26	28
Zn	62	73	102	72	40	99
Pb	-	26	24	27	25	26

	56-64	56-78	57-61	57-63	57-77	57-79
	Sh	L	S	S	F	F
SiO_2	61.78	63.69	56.29	75.82	61.51	60.64
TiO_2	0.62	0.68	0.39	0.40	0.85	0.82
Al_2O_3	17.27	11.65	10.60	9.81	15.06	13.39
Fe_2O_3	0.69	-	0.51	0.35	1.20	1.84
FeO	6.00	6.35	3.80	2.60	5.29	5.51
MnO	0.11	0.08	0.09	0.05	0.09	0.11
MgO	4.50	3.94	4.27	2.47	4.42	5.89
CaO	0.94	5.74	9.86	0.90	2.23	5.22
Na_2O	2.12	1.86	1.95	3.48	3.91	2.70
K_2O	3.40	1.42	1.38	1.61	2.86	1.37
P_2O_5	0.12	0.15	0.13	0.13	0.24	0.18
H_2O^+	2.48	2.48	2.11	1.04	0.88	2.24
H_2O^-	0.22	0.17	0.19	0.18	0.15	0.24
LOI	1.05	2.39	8.35	1.50	0.48	1.14
Total	101.30	100.60	99.92	100.34	99.17	101.29
Li	179	54	56	87	88	59
Rb	117	41	50	57	95	42
Be	-	2	1	4	-	4
Sr	219	339	103	263	490	513
Y	24	10	12	11	17	11
Zr	206	276	176	187	255	252
Cr	121	207	158	110	109	162
Ni	65	66	65	63	77	89
Cu	35	28	27	28	26	27
Zn	91	57	62	29	80	74
Pb	29	29	91	17	16	20

	58-62	58-64	58-78	58-80	59-63	59-65
	F	L	L	L	S	B
SiO_2	59.55	67.47	70.01	69.63	75.26	70.17
TiO_2	0.81	0.73	0.69	0.65	0.50	0.62
Al_2O_3	15.71	12.55	12.61	10.74	7.67	12.15
Fe_2O_3	0.72	0.24	0.55	0.21	-	0.25
FeO	4.81	4.77	4.29	5.07	3.92	3.81
MnO	0.10	0.07	0.08	0.06	0.07	0.01
MgO	3.46	3.77	3.62	3.25	2.48	2.89
CaO	2.92	3.00	2.05	2.64	2.96	3.17
Na_2O	2.56	2.36	2.90	1.71	1.58	1.24
K_2O	3.13	2.33	2.42	2.30	1.28	2.63
P_2O_5	0.27	0.14	0.17	0.13	0.08	0.11
H_2O^+	1.99	1.01	0.71	2.07	1.61	1.09
H_2O^-	0.13	0.06	0.11	0.12	0.01	0.08
LOI	4.23	0.70	0.57	2.67	2.87	0.70
Total	100.39	99.20	100.78	101.25	100.29	99.01
Li	63	88	75	69	64	140
Rb	88	83	75	79	48	127
Be	2	2	4	3	2	2
Sr	455	317	350	148	223	347
Y	17	17	14	15	11	18
Zr	249	291	287	276	253	288
Cr	116	174	170	144	126	246
Ni	63	71	83	69	33	76
Cu	39	22	23	24	24	26
Zn	81	61	69	54	58	60
Pb	29	26	30	20	29	21

	59-77	59-79	59-81	60-64	60-78	60-80
	L	Sh	L	F	B	B
SiO_2	67.37	63.36	62.78	61.88	73.18	71.61
TiO_2	0.73	0.68	0.71	0.83	0.66	0.67
Al_2O_3	12.40	15.19	12.10	14.95	9.85	10.40
Fe_2O_3	0.92	1.34	0.01	0.99	-	0.49
FeO	4.44	4.81	4.52	3.52	4.18	4.26
MnO	0.06	0.08	0.12	0.10	0.06	0.07
MgO	4.27	4.75	4.02	2.33	3.60	3.96
CaO	2.38	3.40	5.64	2.23	2.04	1.48
Na_2O	2.08	1.46	2.43	3.75	1.97	2.13
K_2O	3.15	3.21	1.83	3.17	1.85	1.79
P_2O_5	0.13	0.16	0.14	0.21	0.14	0.13
H_2O^+	0.71	0.96	2.52	1.42	1.16	1.80
H_2O^-	0.07	0.14	0.24	0.18	0.30	0.20
LOI	0.66	1.26	4.19	3.70	1.06	1.41
Total	99.37	100.80	101.25	99.26	100.05	100.40
Li	86	123	148	73	106	86
Rb	107	130	83	97	59	58
Be	2	5	2	3	2	1
Sr	196	257	298	346	214	227
Y	18	22	15	16	16	14
Zr	254	153	242	275	297	283
Cr	214	181	133	82	354	242
Ni	115	97	66	47	90	63
Cu	26	34	23	27	26	24
Zn	71	78	60	62	56	77
Pb	33	38	26	27	26	21

	61-63	61-65	61-77	61-79	62-64	62-66
	S	F	Sh	B	L	S
SiO_2	73.18	66.48	60.99	71.37	69.93	69.98
TiO_2	0.58	0.75	0.45	0.71	0.62	0.53
Al_2O_3	8.01	13.57	16.12	10.28	11.99	13.61
Fe_2O_3	0.61	1.53	0.69	0.27	0.12	0.35
FeO	2.75	4.17	4.22	4.51	4.19	3.20
MnO	0.05	0.08	0.26	0.05	0.07	0.07
MgO	2.19	3.39	4.30	3.64	2.72	2.56
CaO	3.98	2.63	2.39	1.83	1.20	2.29
Na_2O	1.29	2.91	2.37	1.90	2.74	2.87
K_2O	1.07	2.47	2.78	2.15	2.70	2.35
P_2O_5	0.09	0.19	0.10	0.16	0.13	0.10
H_2O^+	1.49	1.36	1.16	1.83	1.71	1.36
H_2O^-	0.17	0.19	0.55	0.11	0.09	0.11
LOI	3.69	0.71	2.20	-	1.41	1.07
Total	99.15	100.43	98.58	98.81	99.62	100.00
Li	57	82	225	64	72	98
Rb	54	81	166	74	70	76
Be	-	3	2	-	2	2
Sr	173	513	283	238	301	266
Y	12	18	9	15	15	14
Zr	244	337	210	290	283	206
Cr	78	125	174	287	124	80
Ni	28	78	131	81	48	60
Cu	24	29	44	28	25	23
Zn	39	70	97	56	53	28
Pb	15	31	37	24	28	27

	62-78	62-80	63-65	63-67	63-77	63-79
	B	L	C	L	Sh	L
SiO_2	70.87	66.50	66.43	65.07	61.01	64.37
TiO_2	0.74	0.70	0.66	0.80	0.80	0.79
Al_2O_3	10.11	13.71	13.32	13.45	15.35	13.31
Fe_2O_3	-	0.60	1.28	0.35	0.02	1.00
FeO	4.88	4.83	2.29	5.01	6.16	5.51
MnO	0.06	0.06	0.08	0.08	0.08	0.08
MgO	4.42	4.61	2.61	4.24	5.72	5.38
CaO	1.71	1.45	1.58	1.77	2.01	0.95
Na_2O	1.64	2.58	2.84	2.82	1.74	2.37
K_2O	2.25	2.09	3.09	2.51	4.31	2.56
P_2O_5	0.13	0.15	0.18	0.17	0.14	0.14
H_2O^+	1.61	2.39	1.70	1.95	1.86	2.55
H_2O^-	0.11	0.17	0.21	0.15	0.23	0.18
LOI	1.32	0.60	2.74	0.82	1.77	0.92
Total	99.85	100.44	99.01	99.19	101.20	100.11
Li	135	183	66	146	216	152
Rb	73	82	95	116	180	86
Be	4	2	2	2	3	-
Sr	177	283	160	536	245	215
Y	14	16	20	15	26	16
Zr	320	332	253	264	260	225
Cr	357	182	72	138	188	170
Ni	76	103	51	58	107	94
Cu	25	28	26	26	33	25
Zn	56	79	487	53	65	55
Pb	35	41	195	26	40	19

	64-66	64-68	64-76	64-78	65-67	65-69
	L	L	L	L	F	L
SiO_2	67.27	64.96	61.23	68.29	63.03	69.81
TiO_2	0.87	0.70	0.85	0.73	0.87	0.77
Al_2O_3	12.61	12.71	13.10	11.40	14.92	11.97
Fe_2O_3	1.07	-	-	2.07	1.79	0.66
FeO	4.14	5.50	7.57	3.53	4.30	3.79
MnO	0.08	0.10	0.11	0.12	0.09	0.10
MgO	3.79	4.32	6.58	4.21	3.71	3.10
CaO	1.33	1.45	0.85	1.21	2.98	1.51
Na_2O	2.86	2.98	3.40	2.24	2.62	2.72
K_2O	2.26	2.64	2.14	2.31	2.47	2.51
P_2O_5	0.18	0.18	0.16	0.13	0.18	0.17
H_2O^+	1.94	2.14	3.15	1.45	1.94	1.04
H_2O^-	0.13	0.20	0.21	0.24	0.23	0.16
LOI	1.03	0.86	1.62	2.37	0.75	0.77
Total	99.53	98.74	100.97	100.30	99.88	99.08
Li	128	193	141	118	96	105
Rb	70	101	67	73	76	95
Be	-	3	2	1	-	-
Sr	241	379	217	149	640	294
Y	17	20	13	15	16	18
Zr	332	268	252	264	275	381
Cr	199	198	222	163	96	157
Ni	73	69	67	62	64	55
Cu	24	28	25	26	30	26
Zn	51	46	72	53	80	79
Pb	19	20	16	5	20	35

	65-71	65-73	65-75	65-77	66-68	66-70
	L	Sh	L	F	F	L
SiO_2	66.09	63.51	69.30	62.04	64.78	63.66
TiO_2	0.68	0.66	0.50	0.90	0.74	0.83
Al_2O_3	13.94	15.62	11.91	13.43	14.72	15.22
Fe_2O_3	0.91	1.40	0.43	0.72	0.65	0.83
FeO	4.21	5.72	4.28	5.83	4.12	4.98
MnO	0.09	0.46	0.07	0.09	0.07	0.06
MgO	3.88	4.13	2.77	5.45	2.73	4.72
CaO	1.33	0.95	0.64	3.09	2.08	1.14
Na_2O	2.59	2.20	2.38	2.67	4.10	2.43
K_2O	3.23	3.56	2.32	1.65	2.68	3.64
P_2O_5	0.18	0.06	0.15	0.21	0.20	0.26
H_2O^+	1.34	1.46	1.88	2.33	1.60	2.79
H_2O^-	0.21	0.15	0.15	0.23	0.14	0.18
LOI	0.70	0.91	1.61	0.97	1.09	0.78
Total	99.38	100.79	98.39	99.61	99.70	101.52
Li	165	139	71	85	67	113
Rb	119	136	78	52	68	120
Be	5	2	1	2	2	5
Sr	330	129	192	450	317	284
Y	19	19	17	12	17	19
Zr	270	162	285	276	246	269
Cr	100	177	157	236	65	114
Ni	65	131	81	78	49	101
Cu	25	32	22	30	27	21
Zn	73	136	62	72	57	156
Pb	23	28	15	18	21	66

	66-72	66-74	66-76	67-69	67-71	67-73
	L	L	L	L	L	L
SiO_2	63.24	68.35	65.44	68.62	70.90	66.96
TiO_2	0.66	0.70	0.63	0.69	0.66	0.58
Al_2O_3	14.82	12.44	12.39	11.23	11.49	13.25
Fe_2O_3	0.06	0.41	-	1.37	0.93	1.21
FeO	4.74	4.42	4.60	3.45	3.40	3.98
MnO	0.07	0.06	0.08	0.09	0.06	0.06
MgO	4.34	3.91	3.61	4.00	3.30	4.23
CaO	1.59	2.76	2.94	1.03	0.56	0.92
Na_2O	2.63	2.55	2.99	3.79	2.21	1.99
K_2O	3.94	1.86	2.34	2.28	2.79	3.81
P_2O_5	0.20	0.19	0.15	0.13	0.13	0.14
H_2O^+	2.19	1.63	1.79	2.15	1.92	2.17
H_2O^-	0.18	0.11	0.28	0.21	0.22	0.18
LOI	1.16	1.10	2.13	1.41	0.93	1.06
Total	99.82	100.49	99.37	100.46	99.50	100.54
Li	74	69	56	66	84	83
Rb	113	82	74	73	84	125
Be	-	2	3	-	4	3
Sr	375	408	293	200	162	280
Y	16	17	16	14	14	21
Zr	261	284	317	289	300	306
Cr	119	120	133	123	117	74
Ni	77	92	67	88	84	72
Cu	26	23	26	22	22	21
Zn	68	57	63	46	48	67
Pb	25	18	31	19	19	26

	67-75
	L
SiO_2	65.17
TiO_2	0.72
Al_2O_3	12.49
Fe_2O_3	-
FeO	5.69
MnO	0.07
MgO	3.90
CaO	3.70
Na_2O	2.51
K_2O	2.39
P_2O_5	0.19
H_2O^+	1.96
H_2O^-	0.17
LOI	2.06
Total	101.02
Li	67
Rb	78
Be	2
Sr	354
Y	16
Zr	307
Cr	127
Ni	64
Cu	22
Zn	57
Pb	23

APPENDIX 4.

Chemical analyses of the granite samples.

All granite sample numbers have the prefix 73/G--, e.g. 73/G. 49-65, but for clarity this is not included in the numbers on the lists of analyses.

CB.	coarse grained biotite granite.
CBM.	coarse grained biotite-muscovite granite.
CMB.	coarse grained muscovite-biotite granite.
FBM.	fine grained biotite-muscovite granite.
FMB.	fine grained muscovite-biotite granite.
FM.	fine grained muscovite granite.

Figures 1 to 4 refer to geochemical clusters.

Major elements are in weight percent and trace elements in parts per million.

	49-65	49-67	49-69	49-71	50-66	50-68
	CB	CB	CBM	CMB	CBM	CBM
	1	1	2	3	2	2
SiO_2	70.02	72.92	73.45	74.03	71.41	74.11
TiO_2	0.41	0.29	0.42	0.16	0.23	0.19
Al_2O_3	14.82	14.79	14.42	14.88	15.14	14.44
Fe_2O_3	1.03	-	0.26	0.89	1.06	0.14
FeO	1.72	1.94	1.44	0.94	0.68	1.56
MnO	0.06	0.06	0.06	0.04	0.05	0.05
MgO	1.07	1.02	0.56	0.68	0.66	0.47
CaO	1.22	1.52	0.58	0.51	0.19	0.46
Na_2O	3.32	3.18	3.10	3.52	2.99	3.22
K_2O	5.22	5.10	5.10	5.21	5.83	5.50
P_2O_5	0.17	0.13	0.13	0.09	0.10	0.14
H_2O^+	0.38	0.63	0.41	0.28	0.58	0.61
H_2O^-	0.22	0.17	0.17	0.34	0.47	0.19
Total	99.66	101.75	100.10	101.57	99.39	101.08
Li	393	265	404	208	266	215
Rb	261	271	316	322	314	303
Be	6	6	5	6	8	6
Sr	200	219	135	155	219	213
Ba	729	798	545	685	681	745
Y	16	15	17	18	18	18
La	45	47	37	28	36	37
Ce	117	108	95	64	90	93
Nd	55	37	57	29	58	54
Zr	209	211	148	125	156	164
Ni	18	15	16	34	25	17
Cu	8	9	9	10	11	9
Zn	47	45	40	23	38	43
Pb	28	27	31	30	28	29

	50-70	50-72	51-65	51-67	51-69	51-71
	CMB	CBM	CBM	CBM	CBM	CBM
	2	2	2	2	2	2
SiO_2	74.73	71.85	72.67	73.38	73.42	72.86
TiO_2	0.30	0.23	0.28	0.39	0.41	0.24
Al_2O_3	14.48	14.20	14.11	14.48	14.40	13.82
Fe_2O_3	0.25	0.28	0.19	1.06	-	-
FeO	1.35	1.24	1.25	0.60	1.44	1.58
MnO	0.06	0.04	0.05	0.05	0.05	0.06
MgO	0.40	0.49	0.72	0.43	0.77	0.43
CaO	0.73	0.60	0.88	0.26	1.16	0.60
Na_2O	3.43	3.29	3.10	3.09	3.04	3.47
K_2O	5.29	5.26	5.40	5.21	4.80	5.30
P_2O_5	0.12	0.10	0.12	0.13	0.13	0.11
H_2O^+	0.52	0.44	0.54	0.39	0.78	0.28
H_2O^-	0.23	0.16	0.18	0.32	0.06	0.39
Total	101.89	98.18	99.49	99.79	100.46	99.14
Li	288	271	362	251	302	275
Rb	340	318	310	315	288	298
Be	16	9	5	5	8	8
Sr	153	171	175	144	158	127
Ba	562	573	646	609	623	501
Y	20	18	18	17	18	18
La	40	28	44	49	52	43
Ce	83	69	101	99	106	81
Nd	52	56	61	31	21	48
Zr	131	139	160	155	152	132
Ni	18	27	23	18	39	18
Cu	9	9	9	15	9	9
Zn	40	40	41	46	42	38
Pb	33	30	27	33	37	32

	51-73	52-64	52-66	52-68	52-74	53-65
	CBM	CBM	CBM	CBM	CBM	CBM
	3	2	3	2	2	2
SiO_2	73.30	72.72	74.32	72.35	72.11	72.20
TiO_2	0.17	0.48	0.14	0.29	0.23	0.30
Al_2O_3	14.00	13.56	13.20	15.13	13.55	14.99
Fe_2O_3	0.63	0.85	1.99	0.07	0.15	0.50
FeO	1.08	1.40	0.56	1.49	1.53	1.16
MnO	0.06	0.50	0.03	0.05	0.05	0.05
MgO	0.71	0.38	0.33	0.43	0.64	0.53
CaO	0.54	0.39	0.90	0.84	0.60	1.97
Na_2O	3.22	4.44	3.10	2.81	3.33	2.89
K_2O	5.34	5.75	4.80	5.42	4.91	4.93
P_2O_5	0.09	0.14	0.05	0.13	0.08	0.13
H_2O^+	0.64	0.50	0.02	0.47	0.68	0.52
H_2O^-	0.10	0.23	0.10	0.40	0.22	0.35
Total	99.88	100.89	99.45	99.88	98.08	100.52
Li	258	294	222	318	272	330
Rb	303	307	264	303	283	310
Be	9	5	-	7	6	4
Sr	155	165	103	139	154	136
Ba	604	635	420	552	549	603
Y	19	19	16	18	19	18
La	26	38	25	29	43	12
Ce	70	89	54	81	103	99
Nd	48	27	41	24	48	30
Zr	121	160	102	133	147	147
Ni	-	10	19	-	23	20
Cu	9	10	8	10	9	9
Zn	32	46	23	43	43	37
Pb	30	28	33	31	35	31

	53-67	53-69	53-71	53-73	54-64	54-66
	CBM	CBM	CBM	CBM	CBM	CBM
	2	3	2	2	2	2
SiO_2	72.95	74.89	72.81	72.40	72.33	71.85
TiO_2	0.17	0.28	0.30	0.27	0.25	0.19
Al_2O_3	14.74	13.71	14.34	14.37	14.17	14.20
Fe_2O_3	0.24	-	1.09	0.47	0.30	0.49
FeO	0.92	0.89	0.72	1.28	1.41	1.17
MnO	0.04	0.05	0.05	0.05	0.05	0.04
MgO	0.42	0.26	0.74	0.69	0.64	0.54
CaO	1.37	0.38	0.59	1.18	0.31	0.97
Na_2O	3.42	3.53	3.16	2.89	3.24	3.02
K_2O	5.09	4.97	5.30	5.16	5.32	5.59
P_2O_5	0.08	0.08	0.14	0.12	0.14	0.13
H_2O^+	0.33	0.55	0.44	0.41	0.57	0.55
H_2O^-	0.10	0.26	0.10	0.14	0.34	0.20
Total	99.87	99.85	99.78	99.43	99.07	98.94
Li	250	412	288	292	106	282
Rb	293	299	301	299	277	310
Be	12	6	5	6	6	6
Sr	143	120	159	165	221	163
Ba	545	620	606	621	739	687
Y	17	17	16	20	15	17
La	26	24	31	38	40	35
Ce	75	64	86	94	89	90
Nd	22	29	50	59	52	54
Zr	114	118	159	157	164	145
Ni	21	10	10	21	19	20
Cu	9	9	9	10	9	9
Zn	30	35	43	45	43	39
Pb	35	36	29	36	31	31

	54-68	54-70	54-72	54-74	55-65	55-69
	FBM	FBM	CBM	CBM	CBM	FMB
	3	3	2	2	2	3
SiO_2	75.07	74.32	71.81	73.92	72.03	75.67
TiO_2	0.27	0.19	0.40	0.31	0.24	0.12
Al_2O_3	13.91	14.44	14.67	13.95	13.83	14.36
Fe_2O_3	0.18	-	0.02	0.51	0.04	0.07
FeO	0.83	1.02	1.55	1.55	1.46	0.64
MnO	0.05	0.04	0.05	0.06	0.05	0.04
MgO	0.26	0.45	0.55	0.68	0.81	0.28
CaO	0.27	0.78	0.78	1.12	1.33	0.71
Na_2O	3.53	3.14	2.87	3.18	2.89	3.12
K_2O	5.34	4.23	5.59	4.82	5.72	5.50
P_2O_5	0.09	0.08	0.13	0.12	0.13	0.13
H_2O^+	0.56	0.64	0.35	0.82	0.61	0.50
H_2O^-	0.35	0.17	0.43	0.25	0.30	0.28
Total	100.71	99.50	99.20	101.29	99.44	101.42
Li	254	236	272	173	220	203
Rb	320	290	295	276	304	327
Be	9	4	7	5	6	8
Sr	103	115	165	204	201	83
Ba	603	620	703	519	779	395
Y	20	20	20	17	18	16
La	22	35	43	36	36	22
Ce	67	55	88	106	99	52
Nd	16	24	57	90	29	<10
Zr	99	115	158	170	150	78
Ni	-	38	17	18	20	16
Cu	9	8	9	8	9	9
Zn	33	30	39	46	39	33
Pb	37	36	33	31	30	30

	55-71	55-73	55-75	56-68	56-70	56-72
	FBM	CBM	CB	FMB	FMB	CBM
	3	2	1	3	3	2
SiO_2	72.39	73.05	68.77	74.00	74.56	74.41
TiO_2	0.26	0.21	0.59	0.13	0.21	0.31
Al_2O_3	13.82	14.33	14.89	14.91	14.76	14.64
Fe_2O_3	0.79	0.57	0.55	0.06	0.26	0.41
FeO	0.57	1.03	2.24	1.07	0.57	1.20
MnO	0.05	0.05	0.07	0.05	0.05	0.05
MgO	0.56	0.63	1.31	0.21	0.09	0.67
CaO	0.45	0.58	1.84	0.18	0.20	0.68
Na_2O	3.07	2.89	4.28	3.09	3.04	3.21
K_2O	5.34	5.37	4.60	5.36	4.87	5.29
P_2O_5	0.08	0.12	0.21	0.16	0.17	0.12
H_2O^+	0.32	0.41	0.33	0.39	0.39	0.61
H_2O^-	0.30	0.16	0.24	0.40	0.28	0.16
Total	98.00	99.40	99.92	100.01	99.45	101.76
Li	242	207	316	268	220	256
Rb	322	284	226	331	315	299
Be	6	7	5	4	5	6
Sr	101	202	250	110	114	201
Ba	583	644	923	462	355	660
Y	19	21	15	17	16	18
La	< 11	35	61	18	18	36
Ce	71	91	142	55	42	87
Nd	31	55	60	< 10	20	33
Zr	101	158	253	93	75	146
Ni	19	18	20	15	15	19
Cu	9	9	9	9	8	10
Zn	31	42	53	49	30	42
Pb	29	30	29	15	32	32

	56-74	56-76	57-65	57-69	57-71	57-73
	CBM	CB	CBM	FM	FMB	CBM
	2	1	2	3	3	2
SiO_2	72.86	71.50	72.25	73.21	73.81	74.50
TiO_2	0.26	0.49	0.31	0.15	0.29	0.26
Al_2O_3	14.08	13.97	13.95	14.30	14.83	14.01
Fe_2O_3	0.30	0.02	1.44	0.35	1.74	0.19
FeO	1.43	1.92	0.85	0.74	0.83	1.45
MnO	0.05	0.06	0.05	0.05	0.05	0.06
MgO	0.53	0.90	0.43	0.25	0.36	0.76
CaO	0.30	1.53	0.76	0.38	0.62	0.68
Na_2O	4.74	3.14	3.46	4.91	3.22	2.93
K_2O	5.77	5.20	5.99	5.40	4.91	5.12
P_2O_5	0.13	0.14	0.10	0.14	0.08	0.12
H_2O^+	1.07	0.64	0.30	0.55	0.37	0.32
H_2O^-	-	0.15	0.38	0.20	0.27	0.53
Total	101.52	99.66	100.27	100.63	101.38	100.93
Li	112	305	323	291	340	217
Rb	264	252	343	446	304	302
Be	5	8	7	14	10	4
Sr	193	229	190	26	111	162
Ba	650	787	675	90	552	611
Y	16	15	20	19	17	22
La	40	46	40	12	27	49
Ce	98	118	80	< 5	66	96
Nd	58	42	57	< 10	11	19
Zr	150	175	147	27	106	157
Ni	20	17	16	18	31	31
Cu	9	10	11	8	9	9
Zn	42	41	40	16	32	45
Pb	27	32	33	21	41	36

	57-75	58-66	58-68	58-70	58-72	58-74
	CBM	CBM	FMB	FMB	CBM	CBM
	2	2	3	3	2	2
SiO_2	73.06	72.62	74.93	75.78	73.49	74.35
TiO_2	0.33	0.16	0.12	0.18	0.19	0.24
Al_2O_3	13.90	14.37	13.86	14.11	14.24	14.52
Fe_2O_3	0.36	0.03	0.54	0.52	2.16	0.42
FeO	1.36	1.22	0.88	0.07	0.60	1.27
MnO	0.05	0.05	0.04	0.04	0.06	0.04
MgO	0.49	0.63	0.33	0.03	0.64	0.61
CaO	0.63	0.97	0.36	0.70	0.61	1.01
Na_2O	3.15	3.12	3.27	4.77	2.85	3.28
K_2O	5.41	5.20	5.24	3.97	5.73	5.35
P_2O_5	0.11	0.13	0.10	0.11	0.12	0.14
H_2O^+	0.57	0.54	0.46	0.31	0.34	0.61
H_2O^-	0.24	0.28	0.13	0.27	0.37	0.12
Total	99.66	99.32	100.26	100.86	101.40	101.96
Li	183	276	158	403	183	281
Rb	292	304	314	512	295	287
Be	6	4	5	17	3	5
Sr	308	161	109	50	214	159
Ba	823	649	588	9	745	675
Y	17	18	12	40	20	18
La	28	35	34	22	38	40
Ce	92	95	< 5	15	91	107
Nd	88	30	31	< 10	33	42
Zr	170	162	98	20	134	165
Ni	18	14	12	—	19	15
Cu	9	9	10	9	9	9
Zn	41	41	25	36	38	43
Pb	33	31	30	24	31	27

	58-76	59-67	59-69	59-71	59-75	60-66
	CB	CBM	FBM	CMB	CBM	CBM
	1	2	3	3	1	2
SiO_2	69.98	72.24	74.49	74.79	71.16	71.89
TiO_2	0.50	0.31	0.12	0.12	0.29	0.26
Al_2O_3	16.08	14.30	14.18	13.75	14.41	14.44
Fe_2O_3	0.86	-	0.25	0.41	-	0.98
FeO	1.79	1.43	0.89	0.90	1.79	1.03
MnO	0.06	0.05	0.05	0.07	0.04	0.06
MgO	1.08	0.43	0.26	0.29	0.85	0.63
CaO	0.76	0.69	0.21	0.67	0.99	1.25
Na_2O	3.50	4.97	3.08	3.61	2.71	2.76
K_2O	5.06	5.90	5.07	5.18	5.72	4.90
P_2O_5	0.18	0.13	0.10	0.06	0.12	0.15
H_2O^+	0.64	0.30	0.25	0.15	0.57	0.51
H_2O^-	0.20	0.58	0.29	0.23	0.21	0.17
Total	100.69	101.33	99.24	100.23	98.86	99.03
Li	261	272	331	317	207	318
Rb	215	302	286	318	265	301
Be	2	7	3	6	2	4
Sr	288	144	113	93	194	154
Ba	1044	652	572	429	822	662
Y	17	17	16	18	16	19
La	79	32	28	23	42	35
Ce	148	88	65	21	96	95
Nd	69	53	61	27	47	27
Zr	250	133	104	90	182	154
Ni	16	19	35	22	40	40
Cu	10	8	9	9	9	9
Zn	48	42	30	31	40	45
Pb	29	30	34	40	35	26

	60-68	60-70	60-72	60-74	60-76	61-67
	CBM	FBM	CBM	CBM	CBM	CB
	2	3	2	2	2	2
SiO_2	72.93	74.85	71.94	72.13	72.31	73.52
TiO_2	0.34	0.33	0.28	0.33	0.31	0.25
Al_2O_3	14.32	13.44	13.97	14.68	14.17	14.02
Fe_2O_3	-	0.34	0.86	-	0.20	0.23
FeO	2.30	0.59	1.51	1.53	1.24	1.44
MnO	0.05	0.04	0.06	0.04	0.04	0.06
MgO	0.72	0.30	0.71	0.48	0.53	0.70
CaO	0.93	0.39	1.04	0.73	0.76	1.04
Na_2O	3.44	3.33	3.05	2.90	3.23	2.96
K_2O	4.92	4.76	3.69	5.70	5.58	5.11
P_2O_5	0.12	0.15	0.13	0.12	0.13	0.09
H_2O^+	0.67	0.34	0.69	0.58	0.37	0.54
H_2O^-	0.23	0.22	0.09	0.20	0.23	0.09
Total	100.97	98.97	98.02	99.42	99.10	100.05
Li	288	324	312	269	197	219
Rb	315	305	329	312	283	289
Be	4	5	6	9	8	5
Sr	153	114	164	135	154	185
Ba	627	565	561	636	632	700
Y	20	16	19	17	15	17
La	39	15	44	37	28	52
Ce	92	< 5	99	82	71	105
Nd	27	26	29	46	24	58
Zr	151	86	140	133	129	166
Ni	-	17	20	17	18	14
Cu	9	9	9	9	9	9
Zn	42	21	45	35	36	41
Pb	33	21	30	33	36	31

	61-69	61-71	61-73	61-75	62-68	62-70
	CBM	CBM	CBM	CB	CBM	CBM
	2	2	2	1	2	2
SiO_2	71.94	71.84	74.17	70.86	72.56	73.75
TiO_2	0.38	0.28	0.31	0.27	0.28	0.25
Al_2O_3	14.37	14.50	15.34	14.99	14.41	14.42
Fe_2O_3	0.26	0.28	-	0.53	0.28	0.50
FeO	1.34	1.27	1.53	1.55	1.44	1.08
MnO	0.06	0.05	0.05	0.06	0.06	0.05
MgO	0.45	0.44	0.70	1.15	0.76	0.62
CaO	0.76	0.85	0.96	1.36	0.75	0.82
Na_2O	3.20	3.23	2.94	2.64	3.16	3.12
K_2O	5.34	5.36	4.63	5.48	5.25	5.36
P_2O_5	0.14	0.13	0.13	0.13	0.11	0.13
H_2O^+	0.71	0.43	0.55	0.53	0.53	0.31
H_2O^-	0.19	0.42	0.36	0.30	0.38	0.24
Total	99.14	99.08	101.67	99.85	99.97	100.65
Li	315	315	266	195	178	248
Rb	311	342	301	245	270	300
Be	7	10	5	4	2	7
Sr	145	147	173	243	234	176
Ba	651	565	645	960	697	669
Y	18	19	18	18	17	18
La	49	37	39	45	49	45
Ce	103	91	89	132	107	96
Nd	52	25	37	45	39	59
Zr	151	142	160	248	159	154
Ni	18	16	20	29	33	38
Cu	9	9	9	11	9	9
Zn	43	40	43	48	44	43
Pb	32	26	30	34	41	39

	62-72	62-74	62-76	63-69	63-71	63-73
	CBM	CB	CBM	CBM	CBM	CBM
	2	1	2	2	3	2
SiO_2	74.11	71.04	73.38	72.18	71.08	73.48
TiO_2	0.24	0.39	0.30	0.37	0.19	0.30
Al_2O_3	14.57	14.68	13.71	14.35	14.98	13.32
Fe_2O_3	0.40	0.50	0.73	-	0.93	0.58
FeO	1.33	1.82	1.32	1.63	0.70	1.39
MnO	0.04	0.06	0.05	0.05	0.05	0.05
MgO	0.58	0.83	0.42	0.62	0.59	0.48
CaO	0.59	1.07	0.81	1.07	0.93	0.43
Na_2O	3.32	3.04	4.83	3.15	3.63	3.71
K_2O	5.50	5.23	4.90	5.57	5.44	5.35
P_2O_5	0.13	0.15	0.14	0.10	0.09	0.12
H_2O^+	0.56	0.72	0.50	0.41	0.46	0.69
H_2O^-	0.13	0.18	0.19	0.36	0.26	0.15
Total	101.50	99.17	101.28	99.86	99.33	100.05
Li	282	196	244	287	165	159
Rb	303	240	252	309	305	241
Be	4	6	6	4	6	4
Sr	145	230	209	161	173	263
Ba	661	828	718	636	599	724
Y	19	15	17	16	16	17
La	41	71	30	59	39	64
Ce	91	118	98	80	69	109
Nd	53	62	24	58	48	58
Zr	157	235	170	162	122	192
Ni	21	-	15	19	36	22
Cu	9	9	8	9	9	9
Zn	42	42	37	74	28	37
Pb	26	27	25	39	30	26

	63-75	64-70	64-72	64-74
	CBM	CBM	CB	CB
	2	2	1	1
SiO_2	73.05	74.13	73.20	69.66
TiO_2	0.27	0.38	0.33	0.29
Al_2O_3	14.73	13.51	14.85	14.39
Fe_2O_3	0.07	1.01	0.13	1.38
FeO	1.73	1.36	2.08	1.34
MnO	0.05	0.05	0.05	0.05
MgO	0.74	0.35	0.84	1.01
CaO	1.44	0.86	1.08	1.24
Na_2O	3.65	3.78	3.21	2.81
K_2O	4.95	4.77	5.18	5.20
P_2O_5	0.11	0.11	0.14	0.14
H_2O^+	0.42	0.37	0.58	0.45
H_2O^-	0.26	0.14	0.17	0.18
Total	101.47	100.82	101.84	98.14
Li	223	213	249	321
Rb	258	271	250	263
Be	6	7	6	6
Sr	191	175	216	192
Ba	667	653	753	693
Y	18	18	19	17
La	41	41	48	49
Ce	107	92	104	101
Nd	92	29	66	57
Zr	171	158	183	181
Ni	10	19	37	28
Cu	9	10	10	10
Zn	38	33	41	37
Pb	28	30	31	26

APPENDIX 5.

CIPW - and Mesonormative analyses of the granite samples.

CIPW - NORMATIVE MINERALS.

	49-65	49-67	49-69	49-71	50-66
Quartz	26.23	29.06	33.37	31.42	30.58
Orthoclase	30.84	30.13	30.13	30.74	34.44
Albite	28.08	26.90	26.22	29.77	25.29
Anorthite	4.94	6.69	2.03	1.94	0.29
Corundum	1.90	1.59	3.06	2.74	4.08
Hypersthene En	2.66	2.54	1.39	1.69	1.64
Hypersthene Fs	1.74	3.19	1.85	0.80	0.09
Magnetite	1.49	-	0.38	1.29	1.54
Ilmenite	0.78	0.55	0.80	0.30	0.44
Apatite	0.40	0.31	0.31	0.21	0.24
Water	0.60	0.80	0.58	0.62	1.05
Differentiation Index	85.15	86.09	89.72	91.97	90.31

MESONORMATIVE MINERALS.

	49-65	49-67	49-69	49-71	50-66
Quartz	26.73	29.10	32.67	29.83	29.01
Orthoclase	26.61	24.54	26.98	27.85	32.23
Albite	29.73	27.80	27.75	30.91	26.54
Anorthite	3.51	5.53	0.56	1.35	-
Biotite	6.64	7.68	4.91	3.62	2.92
Corundum	2.64	2.08	3.91	3.15	4.52
Sphene	0.85	0.59	0.88	0.33	0.17
Magnetite	1.07	-	0.27	0.91	1.10
Apatite	0.35	0.26	0.27	0.18	0.21
Water	1.85	2.41	1.79	1.87	3.21

CIPW - NORMATIVE MINERALS.

	50-68	50-70	50-72	51-65	51-67
Quartz	31.91	31.87	30.07	30.56	34.65
Orthoclase	32.49	31.25	31.08	31.90	30.78
Albite	27.23	29.01	27.83	26.22	26.13
Anorthite	1.37	2.84	2.32	3.58	0.44
Corundum	2.69	2.07	2.25	1.86	3.60
Hypersthene En	1.17	1.00	1.22	1.79	1.07
Hypersthene Fs	2.53	1.89	1.74	1.77	0.97
Magnetite	0.20	0.36	0.41	0.28	0.39
Ilmenite	0.36	0.57	0.44	0.53	0.74
Apatite	0.33	0.28	0.24	0.28	0.31
Water	0.80	0.75	0.60	0.72	0.71
Differentiation Index	91.64	92.13	88.98	88.69	91.57

MESONORMATIVE MINERALS.

	50-68	50-70	50-72	51-65	51-67
Quartz	30.83	30.29	29.81	30.19	32.74
Orthoclase	28.87	27.92	28.82	28.62	29.52
Albite	28.37	30.00	29.91	27.77	27.69
Anorthite	0.69	1.75	1.52	2.60	-
Biotite	4.84	4.05	4.24	5.15	1.94
Corundum	3.14	2.61	2.81	2.41	4.10
Sphene	0.39	0.61	0.49	0.58	0.26
Magnetite	0.14	0.25	0.30	0.20	1.11
Apatite	0.29	0.24	0.21	0.25	0.27
Water	2.43	2.26	1.88	2.22	2.19

CIPW - NORMATIVE MINERALS

	51-69	51-71	51-73	52-64	52-66
Quartz	33.18	29.60	31.60	23.57	36.18
Orthoclase	28.36	31.31	31.55	33.97	28.36
Albite	25.71	29.35	27.23	37.55	25.45
Anorthite	4.91	2.26	2.90	0.10	4.14
Corundum	2.41	1.55	2.16	-	1.54
Hypersthene En	1.92	1.07	1.77	0.77	0.82
Hypersthene Fs	2.06	2.62	1.29	0.96	-
Magnetite	-	-	0.91	1.23	1.50
Ilmenite	0.78	0.46	0.32	0.91	0.27
Apatite	0.31	0.26	0.21	0.33	0.12
Water	0.84	0.67	0.74	0.73	0.12
Differentiation Index	87.25	90.27	90.38	95.09	90.00

MESONORMATIVE MINERALS

	51-69	51-71	51-73	52-64	52-66
Quartz	32.56	29.33	30.74	22.37	34.75
Orthoclase	24.36	28.24	28.64	31.01	27.35
Albite	26.96	31.19	28.73	38.97	27.56
Anorthite	3.44	1.42	1.49	-	3.72
Biotite	5.84	4.98	4.63	3.52	2.52
Corundum	3.16	2.03	2.58	0.04	1.91
Sphene	0.85	0.50	0.35	0.60	0.30
Magnetite	-	-	0.65	0.87	1.40
Apatite	0.27	0.23	0.19	0.29	0.11
Water	2.57	2.07	2.27	2.21	0.38

CIPW - NORMATIVE MINERALS

	52-68	52-74	53-65	53-67	53-69
Quartz	32.16	30.86	31.30	29.68	33.80
Orthoclase	32.02	29.01	29.13	30.07	29.36
Albite	23.77	28.16	24.44	28.93	29.86
Anorthite	3.32	2.45	8.92	6.27	1.36
Corundum	3.43	1.86	1.63	1.31	2.03
Hypersthene En	1.07	1.59	1.32	1.05	0.65
Hypersthene Fs	2.29	2.40	1.31	1.28	1.26
Magnetite	0.10	0.22	0.72	0.35	-
Ilmenite	0.55	0.44	0.57	0.32	0.53
Apatite	0.31	0.19	0.31	0.19	0.19
Water	0.87	0.90	0.87	0.43	0.81
Differentiation Index	87.95	88.03	84.87	88.67	93.02

MESONORMATIVE MINERALS

Quartz	31.35	30.90	30.12	28.68	32.15
Orthoclase	28.89	25.79	26.31	27.95	27.33
Albite	25.06	30.13	25.62	30.64	31.44
Anorthite	2.29	1.67	7.78	5.67	0.38
Biotite	4.67	5.53	3.94	3.30	2.88
Corundum	4.12	2.37	2.17	1.66	2.58
Sphene	0.60	0.48	0.62	0.35	0.58
Magnetite	0.07	0.16	0.52	0.25	-
Apatite	0.27	0.17	0.27	0.17	0.17
Water	2.67	2.80	2.66	1.33	2.48

CIPW - NORMATIVE MINERALS

	53-71	53-73	54-64	54-66	54-68
Quartz	32.18	31.91	31.00	29.71	32.94
Orthoclase	31.31	30.49	31.43	33.03	31.55
Albite	26.73	24.44	27.40	25.54	29.86
Anorthite	2.01	5.07	0.62	3.96	0.75
Corundum	2.67	2.17	2.86	1.73	2.05
Hypersthene En	1.84	1.72	1.59	1.34	0.65
Hypersthene Fs	0.02	1.61	2.02	1.50	1.02
Magnetite	1.58	0.68	0.43	0.71	0.26
Ilmenite	0.57	0.51	0.47	0.36	0.51
Apatite	0.33	0.28	0.33	0.31	0.21
Water	0.54	0.55	0.91	0.75	0.91
Differentiation Index	90.22	86.84	89.83	88.28	94.35

MESONORMATIVE MINERALS

	53-71	53-73	54-64	54-66	54-68
Quartz	31.06	31.54	30.52	29.14	30.88
Orthoclase	29.25	27.59	28.19	30.62	29.36
Albite	28.37	26.07	29.02	27.21	31.10
Anorthite	0.97	4.15	-	3.31	-
Biotite	3.30	4.87	5.08	4.05	2.56
Corundum	3.33	2.76	3.36	2.16	2.49
Sphene	0.63	0.57	0.37	0.40	0.44
Magnetite	1.14	0.49	0.31	0.51	0.18
Apatite	0.29	0.25	0.29	0.27	0.18
Water	1.67	1.71	2.81	2.33	2.76

CIPW - NORMATIVE MINERALS

	54-70	54-72	54-74	55-65	55-69
Quartz	37.02	30.59	33.00	28.59	34.47
Orthoclase	24.99	33.03	28.48	33.79	32.49
Albite	26.56	24.27	26.90	24.44	26.39
Anorthite	3.35	3.02	4.77	5.75	2.67
Corundum	3.47	2.79	1.76	0.78	2.30
Hypersthene En	1.12	1.37	1.69	2.02	0.70
Hypersthene Fs	1.63	2.26	2.02	2.34	0.99
Magnetite	-	0.03	0.74	0.06	0.10
Ilmenite	0.36	0.76	0.59	0.46	0.23
Apatite	0.19	0.31	0.28	0.31	0.31
Water	0.81	0.78	1.07	0.91	0.78
Differentiation Index	88.57	87.89	88.37	86.83	93.35

MESONORMATIVE MINERALS

	54-70	54-72	54-74	55-65	55-69
Quartz	35.68	30.37	31.82	28.62	32.13
Orthoclase	22.55	29.74	24.54	29.85	30.36
Albite	28.14	25.79	27.88	25.81	27.42
Anorthite	2.68	1.63	3.61	4.89	2.21
Biotite	3.84	5.32	5.23	6.03	2.32
Corundum	4.05	3.61	2.29	1.18	2.62
Sphene	0.40	0.84	0.63	0.50	0.25
Magnetite	-	0.02	0.52	0.04	0.07
Apatite	0.17	0.27	0.25	0.27	0.27
Water	2.50	2.41	3.23	2.80	2.36

CIPW - NORMATIVE MINERALS

	55-71	55-73	55-75	56-68	56-70
Quartz	32.51	33.33	19.71	34.40	37.86
Orthoclase	31.55	31.73	27.18	31.67	28.77
Albite	25.96	24.44	36.20	26.13	25.71
Anorthite	1.71	2.09	7.76	-	-
Corundum	2.37	3.00	0.03	4.03	4.49
Hypersthene En	1.39	1.57	3.26	0.52	0.22
Hypersthene Fs	0.06	1.17	2.81	1.79	0.58
Magnetite	1.15	0.83	0.80	0.09	0.38
Ilmenite	0.49	0.40	1.12	0.25	0.40
Apatite	0.19	0.28	0.50	1.08	1.20
Water	0.64	0.57	0.59	0.79	0.67
Differentiation Index	90.03	89.50	83.08	92.20	92.34

MESONORMATIVE MINERALS

	55-71	55-73	55-75	56-68	56-70
Quartz	31.59	32.54	21.40	32.14	35.28
Orthoclase	30.39	29.35	21.24	29.55	27.99
Albite	27.99	26.06	37.95	27.53	27.36
Anorthite	0.82	1.37	5.63	0.44	0.26
Biotite	2.65	4.04	8.97	3.01	1.38
Corundum	2.99	3.58	0.85	4.19	4.81
Sphene	0.55	0.44	1.22	0.27	0.44
Magnetite	0.84	0.60	0.57	0.06	0.27
Apatite	0.17	0.25	0.43	-	-
Water	2.01	1.77	1.74	2.42	2.08

CIPW - NORMATIVE MINERALS

	56-72	56-74	56-76	57-65	57-69
Quartz	32.74	21.35	27.85	27.23	22.80
Orthoclase	31.25	34.09	30.72	35.39	31.90
Albite	27.15	40.09	26.56	29.26	41.53
Anorthite	2.59	0.11	6.67	3.12	0.97
Corundum	2.69	-	0.73	0.63	0.03
Hypersthene En	1.67	1.23	2.24	1.07	0.62
Hypersthene Fs	1.45	1.91	2.81	-	0.91
Magnetite	0.59	0.43	0.03	2.00	0.51
Ilmenite	0.59	0.49	0.93	0.59	0.28
Apatite	0.28	0.31	0.33	0.24	0.33
Water	0.77	1.07	0.79	0.68	0.75
Differentiation Index	91.14	95.53	85.13	91.89	96.23

MESONORMATIVE MINERALS

	56-72	56-74	56-76	57-65	57-69
Quartz	31.30	20.54	28.44	25.81	21.37
Orthoclase	27.65	29.88	25.98	33.77	29.69
Albite	28.12	40.84	28.05	30.78	42.90
Anorthite	1.47	-	4.95	2.02	0.44
Biotite	4.55	4.54	7.35	2.09	2.17
Corundum	3.28	0.04	1.48	1.12	0.23
Sphene	0.63	0.37	1.02	0.64	0.31
Magnetite	0.42	0.30	0.02	1.49	0.36
Apatite	0.24	0.26	0.29	0.21	0.28
Water	2.32	3.18	2.43	2.08	2.26

CIPW - NORMATIVE MINERALS

	57-71	57-73	57-75	58-66	58-68
Quartz	34.67	34.63	31.49	31.01	34.42
Orthoclase	29.01	30.25	31.96	30.72	30.96
Albite	27.23	24.78	26.64	26.39	27.66
Anorthite	2.55	2.59	2.41	3.96	1.13
Corundum	3.29	2.70	1.98	2.16	2.40
Hypersthene En	0.90	1.89	1.22	1.57	0.82
Hypersthene Fs	-	2.19	1.75	2.04	1.05
Magnetite	2.00	0.28	0.52	0.04	0.78
Ilmenite	0.55	0.49	0.63	0.30	0.23
Apatite	0.19	0.28	0.26	0.31	0.24
Water	0.64	0.85	0.81	0.82	0.59
Differentiation Index	90.91	89.66	90.09	88.12	93.03

MESONORMATIVE MINERALS

	57-71	57-73	57-75	58-66	58-68
Quartz	32.36	33.71	30.70	30.48	32.70
Orthoclase	27.66	26.25	29.11	27.57	29.18
Albite	28.50	25.90	28.17	27.92	29.21
Anorthite	1.52	1.66	1.25	3.40	0.71
Biotite	1.51	5.65	4.37	4.90	2.60
Corundum	3.94	3.26	2.61	2.57	2.77
Sphene	0.60	0.53	0.69	0.33	0.25
Magnetite	1.79	0.20	0.37	0.03	0.56
Apatite	0.16	0.25	0.23	0.27	0.21
Water	1.95	2.59	2.49	2.53	1.81

CIPW - NORMATIVE MINERALS

	58-70	58-72	58-74	58-76	59-67
Quartz	31.63	33.08	31.38	26.70	19.34
Orthoclase	23.46	33.85	31.61	29.90	34.86
Albite	40.34	24.10	27.74	29.60	40.71
Anorthite	2.76	2.24	4.10	2.59	-
Corundum	0.96	2.53	1.83	3.90	-
Hypersthene En	0.07	1.59	1.52	2.69	0.71
Hypersthene Fs	-	-	1.66	1.86	1.46
Magnetite	0.52	1.58	0.61	1.25	-
Ilmenite	0.06	0.36	0.46	0.95	0.59
Apatite	0.26	0.28	0.33	0.43	0.31
Water	0.58	0.71	0.73	0.84	0.88
Differentiation Index	95.43	91.04	90.73	86.19	94.90

MESONORMATIVE MINERALS

	58-70	58-72	58-74	58-76	59-67
Quartz	28.88	31.21	29.99	26.82	17.85
Orthoclase	22.60	31.13	28.02	25.01	31.95
Albite	41.95	25.22	28.69	30.80	41.58
Anorthite	2.08	1.56	3.18	0.84	-
Biotite	0.61	3.59	4.44	6.86	2.55
Corundum	1.27	2.98	2.28	4.85	-
Sphene	0.37	0.39	0.49	1.02	0.62
Magnetite	0.25	1.51	0.43	0.88	-
Apatite	0.23	0.25	0.29	0.37	0.26
Water	1.76	2.16	2.20	2.55	2.62

CIPW - NORMATIVE MINERALS

	59-69	59-71	59-75	60-66	60-68
Quartz	36.03	31.72	29.16	33.56	29.67
Orthoclase	29.95	30.60	33.79	28.95	29.07
Albite	26.05	30.53	22.92	23.34	29.09
Anorthite	0.39	2.93	4.13	5.22	3.83
Corundum	3.49	1.13	2.25	2.68	1.93
Hypersthene En	0.65	0.72	2.12	1.57	1.79
Hypersthene Fs	1.32	1.25	2.88	0.76	3.75
Magnetite	0.36	0.59	-	1.42	-
Ilmenite	0.23	0.23	0.55	0.49	0.65
Apatite	0.24	0.14	0.28	0.36	0.28
Water	0.54	0.38	0.78	0.68	0.90
Differentiation Index	92.03	92.86	85.88	85.85	87.84

MESONORMATIVE MINERALS

	59-69	59-71	59-75	60-66	60-68
Quartz	34.61	30.30	29.74	32.74	29.70
Orthoclase	28.48	28.83	29.60	26.89	23.89
Albite	27.84	32.30	24.43	24.99	30.26
Anorthite	-	2.51	3.13	4.35	2.59
Biotite	2.69	2.68	6.94	3.69	7.35
Corundum	3.99	1.40	2.87	3.32	2.53
Sphene	0.23	0.25	0.61	0.55	0.70
Magnetite	0.26	0.43	-	1.03	-
Apatite	0.21	0.13	0.25	0.32	0.25
Water	1.68	1.17	2.42	2.12	2.73

CIPW - NORMATIVE MINERALS

	60-70	60-72	60-74	60-76	61-67
Quartz	36.19	36.39	30.46	29.37	32.77
Orthoclase	28.12	21.80	33.68	32.97	30.19
Albite	28.16	25.80	24.53	27.32	25.03
Anorthite	0.96	4.31	2.84	2.92	4.57
Corundum	2.46	3.38	2.70	1.75	1.95
Hypersthene En	0.75	1.77	1.19	1.32	1.74
Hypersthene Fs	0.51	1.71	2.34	1.67	2.15
Magnetite	0.49	1.25	-	0.29	0.33
Ilmenite	0.42	0.53	0.63	0.59	0.47
Apatite	0.36	0.31	0.28	0.31	0.21
Water	0.56	0.78	0.78	0.60	0.63
Differentiation Index	92.47	83.99	88.66	89.66	87.99

MESONORMATIVE MINERALS

	60-70	60-72	60-74	60-76	61-67
Quartz	34.61	36.24	30.06	28.97	32.31
Orthoclase	27.04	18.97	30.50	30.32	26.70
Albite	30.15	27.86	26.00	29.10	26.49
Anorthite	0.19	3.39	1.69	1.85	3.69
Biotite	2.11	5.15	5.00	4.43	5.45
Corundum	3.02	4.15	3.41	2.35	2.47
Sphene	0.46	0.60	0.69	0.65	0.52
Magnetite	0.36	0.91	-	0.21	0.24
Apatite	0.32	0.28	0.25	0.27	0.19
Water	1.75	2.45	2.41	1.86	1.94

CIPW - NORMATIVE MINERALS

	61-69	61-71	61-73	61-75	62-68
Quartz	30.22	29.66	35.54	29.34	30.74
Orthoclase	31.55	31.67	27.35	32.38	31.02
Albite	27.06	27.32	24.87	22.33	26.73
Anorthite	2.86	3.37	3.91	5.90	3.00
Corundum	2.28	2.15	4.06	2.56	2.43
Hypersthene En	1.12	1.10	1.74	2.86	1.89
Hypersthene Fs	1.73	1.73	2.39	2.07	2.06
Magnetite	0.38	0.41	-	0.77	0.41
Ilmenite	0.72	0.53	0.59	0.51	0.53
Apatite	0.33	0.31	0.31	0.31	0.26
Water	0.90	0.85	0.91	0.83	0.91
Differentiation Index	88.83	88.64	87.76	84.05	88.48

MESONORMATIVE MINERALS

Quartz	29.55	28.98	34.27	29.65	30.27
Orthoclase	28.80	29.08	23.13	27.78	27.20
Albite	28.67	28.96	25.75	23.55	28.06
Anorthite	1.53	2.39	2.77	4.93	2.01
Biotite	4.30	4.08	5.70	7.02	5.58
Corundum	3.01	2.74	4.75	3.15	3.01
Sphene	0.79	0.58	0.63	0.56	0.58
Magnetite	0.27	0.29	-	0.55	0.29
Apatite	0.29	0.27	0.27	0.27	0.23
Water	2.78	2.62	2.74	2.55	2.78

CIPW - NORMATIVE MINERALS

	62-70	62-72	62-74	62-76	63-69
Quartz	32.22	31.19	29.16	24.34	28.50
Orthoclase	31.67	32.49	30.90	28.95	32.91
Albite	26.39	28.08	25.71	40.85	26.64
Anorthite	3.22	2.08	4.33	1.27	4.65
Corundum	2.31	2.40	2.43	-	1.44
Hypersthene En	1.54	1.44	2.07	0.72	1.54
Hypersthene Fs	1.25	1.79	2.40	0.98	2.47
Magnetite	0.72	0.58	0.72	1.06	-
Ilmenite	0.47	0.46	0.74	0.57	0.70
Apatite	0.31	0.31	0.36	0.33	0.24
Water	0.55	0.69	0.90	0.69	0.77
Differentiation Index	90.28	91.77	85.77	94.14	88.05

MESONORMATIVE MINERALS

	62-70	62-72	62-74	62-76	63-69
Quartz	31.14	29.98	29.25	22.62	28.36
Orthoclase	28.82	29.00	26.67	26.55	29.10
Albite	27.76	29.17	27.11	42.17	28.08
Anorthite	2.33	1.22	2.95	1.23	3.34
Biotite	4.12	4.50	6.43	2.57	5.71
Corundum	2.84	2.89	3.18	-	2.07
Sphene	0.52	0.49	0.81	0.61	0.77
Magnetite	0.52	0.41	0.52	0.74	-
Apatite	0.27	0.27	0.31	0.28	0.21
Water	1.69	2.09	2.76	2.07	2.36

CIPW - NORMATIVE MINERALS

	63-71	63-73	63-75	64-70	64-72
Quartz	26.41	29.39	27.76	31.34	30.07
Orthoclase	32.14	31.61	29.25	28.18	30.60
Albite	30.70	31.38	30.87	31.97	27.15
Anorthite	4.03	1.35	6.42	3.55	4.44
Corundum	1.65	0.93	1.02	0.83	2.34
Hypersthene En	1.47	1.19	1.84	0.87	2.09
Hypersthene Fs	0.30	1.67	2.77	1.13	3.26
Magnetite	1.35	0.84	0.10	1.46	0.19
Ilmenite	0.36	0.57	0.51	0.72	0.63
Apatite	0.21	0.28	0.26	0.26	0.33
Water	0.72	0.84	0.68	0.51	0.75
Differentiation Index	89.25	92.37	87.87	91.49	87.82

MESONORMATIVE MINERALS

Quartz	25.40	28.49	27.43	29.99	29.86
Orthoclase	30.19	28.66	24.69	25.90	25.35
Albite	32.41	32.94	31.99	33.62	28.10
Anorthite	3.35	0.30	5.36	2.20	3.21
Biotite	2.84	4.16	6.19	3.23	7.19
Corundum	2.05	1.42	1.45	1.42	2.94
Sphene	0.39	0.62	0.55	0.79	0.67
Magnetite	0.97	0.60	0.07	1.05	0.13
Apatite	0.19	0.25	0.22	0.23	0.29
Water	2.21	2.57	2.05	1.56	2.26

CIPW - NORMATIVE MINERALS

	64-74
Quartz	29.24
Orthoclase	30.72
Albite	23.77
Anorthite	5.24
Corundum	2.22
Hypersthene En	2.51
Hypersthene Fs	0.93
Magnetite	2.00
Ilmenite	0.55
Apatite	0.33
Water	0.63
Differentiation Index	83.73

MESONORMATIVE MINERALS

Quartz	29.56
Orthoclase	27.86
Albite	25.64
Anorthite	4.30
Biotite	5.40
Corundum	2.88
Sphene	0.62
Magnetite	1.47
Apatite	0.30
Water	1.98

APPENDIX 6

Chemical and normative analyses of the minor intrusive suite.

All minor intrusive rock samples have a format e.g. 72/I 004A and are given in appendix 10, C.

	004A	004B	140	220B
SiO_2	53.79	49.43	50.96	51.88
TiO_2	1.07	1.03	0.69	1.30
Al_2O_3	15.11	15.52	16.09	12.77
Fe_2O_3	1.09	1.16	1.54	0.98
FeO	6.25	8.68	4.57	6.74
MnO	0.28	0.52	0.28	0.30
MgO	8.51	10.95	3.73	11.68
CaO	4.14	5.14	5.10	2.92
Na_2O	3.44	2.63	4.42	1.95
K_2O	2.91	3.82	2.69	2.76
P_2O_5	0.25	0.24	0.30	0.28
H_2O^+	2.58	1.46	3.52	3.32
H_2O^-	0.29	0.13	0.14	0.23
LOI	n.d.	n.d.	6.65	4.02
Total	99.71	100.71	100.68	101.13
Li	227	195	50	140
Rb	151	186	84	93
Be	<2	4	2	2
Sr	470	374	827	131
Y	18	19	10	19
Zr	224	154	186	122
Cr	508	708	40	737
Co	80	60	n.d.	n.d.
Ni	615	458	45	196
Cu	32	38	33	26
Zn	87	168	60	78
Pb	11	29	10	15

	221	679	762	854
SiO_2	58.44	45.59	68.05	57.01
TiO_2	0.79	0.32	0.26	0.70
Al_2O_3	13.40	11.61	14.71	12.55
Fe_2O_3	0.81	0.78	0.53	-
FeO	5.53	7.91	1.69	5.70
MnO	0.28	0.17	0.03	0.11
MgO	8.66	18.41	1.36	8.94
CaO	2.20	8.90	1.92	4.65
Na_2O	3.08	1.04	4.20	3.24
K_2O	2.55	0.57	2.02	1.85
P_2O_5	0.29	0.09	0.10	0.23
H_2O^+	2.93	2.59	1.33	1.75
H_2O^-	0.18	0.26	0.17	0.16
LOI	2.68	2.29	1.75	1.67
Total	101.82	100.53	98.12	98.56
Li	128	101	28	61
Rb	68	24	75	91
Be	2	-	2	1
Sr	261	339	241	286
Y	12	7	11	16
Zr	167	96	169	228
Cr	461	1710	37	168
Co	n.d.	n.d.	n.d.	n.d.
Ni	198	569	28	105
Cu	29	20	26	26
Zn	73	91	44	95
Pb	19	19	29	32

CIPW-NORMATIVE MINERALS

	004A	004B	140	220B
Quartz	-	-	-	2.58
Orthoclase	17.19	22.57	15.89	16.31
Albite	29.09	18.53	37.38	16.49
Anorthite	17.20	19.27	16.13	12.66
Nepheline	-	2.01	-	-
Corundum	-	-	-	1.94
Diopside Wo	0.71	1.95	3.01	-
Diopside En	0.46	1.20	1.70	-
Diopside Fs	0.20	0.63	1.19	-
Hypersthene En	15.57	-	3.09	29.08
Hypersthene Fs	6.85	-	2.16	9.98
Olivine Fo	3.62	18.26	3.15	-
Olivine Fa	1.75	10.52	2.43	-
Magnetite	1.58	1.68	2.23	1.42
Ilmenite	2.03	1.96	1.31	2.47
Apatite	0.59	0.57	0.71	0.66
Water	2.87	1.59	3.66	3.55
Differentiation Index	46.28	43.11	53.27	35.38

MESONORMATIVE MINERALS

	004A	004B	140	220B
Quartz	7.51	0.99	3.00	11.48
Orthoclase	-	-	5.78	-
Albite	28.74	22.28	38.53	16.51
Anorthite	14.13	18.19	15.67	7.67
Hypersthene	11.38	14.65	-	21.60
Actinolite	-	1.52	7.01	-
Edenite	-	-	-	-
Biotite	25.60	34.08	15.45	24.61
Corundum	0.75	-	-	3.70
Sphene	2.08	2.03	1.40	2.56
Magnetite	1.06	1.14	1.56	0.97
Apatite	0.49	0.47	0.61	0.55
Water	8.26	4.64	10.99	10.35

CIPW-NORMATIVE MINERALS

	221	679	762	854
Quartz	10.02	-	29.01	5.72
Orthoclase	15.07	3.37	11.93	10.93
Albite	26.05	8.80	35.52	27.40
Anorthite	9.02	25.33	8.87	14.24
Nepheline	-	-	-	-
Corundum	2.27	-	2.37	-
Diopside Wo	-	7.61	-	3.06
Diopside En	-	5.36	-	1.99
Diopside Fs	-	1.60	-	0.85
Hypersthene En	21.56	10.08	3.39	20.26
Hypersthene Fs	8.70	3.00	2.29	8.66
Olivine Fo	-	21.30	-	-
Olivine Fa	-	7.00	-	-
Magnetite	1.17	1.13	0.77	-
Ilmenite	1.50	0.61	0.49	1.33
Apatite	0.69	0.21	0.24	0.55
Water	3.11	2.85	1.50	1.91
Differentiation Index	51.14	12.71	76.46	44.05

MESONORMATIVE MINERALS

	221	679	762	854
Quartz	17.41	-	30.08	10.61
Orthoclase	-	-	6.93	-
Albite	25.86	0.72	37.92	28.36
Anorthite	5.86	23.55	8.01	13.89
Olivine	-	9.49	-	-
Hypersthene	13.34	26.04	-	15.29
Actinolite	-	-	-	7.14
Edenite	-	25.45	-	-
Biotite	22.55	5.01	8.11	17.05
Corundum	3.35	-	2.96	-
Sphene	1.54	0.62	0.55	1.43
Magnetite	0.79	0.76	0.56	-
Apatite	0.57	0.17	0.21	0.47
Water	8.99	8.19	4.66	5.76

APPENDIX 7

Chemical analyses and numbers of ions per formula unit of separated minerals.

Sample numbers of separated minerals are the same as their host rock and suffixes indicate the mineral concerned:

B = biotite, C = chlorite, M = muscovite and F = felsic fraction i.e. quartz, plagioclase and microcline. Figures in brackets before each sample number refer to the locality of the rock in Figures 40, 43-50.

Biotite analyses:

	(3)50-66B	(5)51-71B	(8)53-69B	(9)54-68B	(1)55-75B
SiO_2	33.29	35.05	33.67	32.56	36.57
TiO_2	2.64	2.50	2.59	2.33	2.64
Al_2O_3	17.58	16.98	17.72	18.20	16.61
Fe_2O_3	-	1.75	0.95	2.54	1.68
FeO	22.37	20.60	21.06	22.05	19.22
MnO	0.47	0.52	0.70	0.76	0.39
MgO	10.32	9.30	8.15	8.42	8.86
CaO	0.16	0.20	0.48	0.31	0.16
Li_2O	0.73	0.72	1.32	1.07	0.53
Na_2O	0.17	0.15	0.13	0.19	0.21
K_2O	6.19	8.40	7.67	4.67	9.57
Rb_2O	0.08	0.13	0.11	n.d.	0.10
P_2O_5	0.05	0.04	0.02	0.04	0.08
H_2O^+	4.13	2.93	3.48		1.60
H_2O^-	0.49	0.41	0.40	10.04	0.45
LOI	2.21	2.23	1.81		3.53
Total	100.80	101.78	100.15	103.18	102.20
* O ≡ F	0.93	0.93	0.76		1.48
Total	99.52	100.48	99.10		100.72
Be	6	2	7	6	2
Sr	3	3	-	n.d.	5
Y	255	270	321	n.d.	251
Zr	64	20	68	n.d.	50
Cr	164	137	135	117	162
Ni	73	65	62	54	88
Cu	83	24	40	23	10
Zn	593	637	745	719	305

* assuming L.O.I. ≡ F.

Biotite analyses.

	(10)56-70B	(7)60-72B	(4)60-74B	(6)61-71B	(2)64-70B
SiO_2	32.95	33.43	36.02	34.46	36.52
TiO_2	2.76	2.71	2.76	2.57	2.32
Al_2O_3	19.08	16.82	17.07	17.04	15.71
Fe_2O_3	2.27	1.38	-	2.06	1.76
FeO	23.36	21.29	20.74	20.02	20.63
MnO	0.99	0.54	0.52	0.57	0.43
MgO	6.98	9.75	9.43	9.65	9.89
CaO	0.24	0.78	0.27	0.62	0.30
Li_2O	0.81	0.83	0.74	1.02	0.57
Na_2O	0.15	0.18	0.15	0.21	0.13
K_2O	4.52	7.34	8.00	7.49	8.52
Rb_2O	n.d.	0.11	0.12	0.10	0.13
P_2O_5	0.04	0.08	0.03	0.05	0.09
H_2O^+	3.63	3.38	2.35	3.30	1.84
H_2O^-	-	0.48	0.44	0.44	0.55
LOI	5.23	1.98	2.53	1.68	2.50
Total	103.01	100.97	101.05	101.18	100.76
$O \equiv F$	2.19	0.83	1.06	0.71	1.05
Total	99.97	99.82	99.58	100.21	100.31
Be	17	12	2	8	2
Sr	n.d.	17	2	12	-
Y	n.d.	223	329	196	228
Zr	n.d.	41	37	43	35
Cr	65	125	151	126	109
Ni	495	71	66	66	71
Cu	83	31	33	21	39
Zn	1150	637	630	708	556

Biotites, numbers of ions on the basis of 24(O,OH, F)

	(3)50-66B		(5)51-71B		(8)53-69B	
Si	5.12	8.00	5.44	8.00	5.25	8.00
Al	2.88		2.56		2.75	
Al	0.31	6.38	0.54	6.39	0.50	6.48
Ti	0.31		0.29		0.30	
Fe^{3+}	-		0.22		0.12	
Fe^{2+}	2.88		2.67		2.75	
Mn	0.06		0.07		0.09	
Mg	2.37		2.15		1.89	
Li	0.45		0.45		0.83	
Ca	0.03	1.31	0.03	1.75	0.08	1.66
Na	0.05		0.05		0.04	
K	1.22		1.66		1.53	
Rb	0.01		0.01		0.01	
OH	4.25		3.04		3.62	

	(1)55-75B		(10)56-70B		(7)60-72B	
Si	5.81	8.00	5.12	8.00	5.21	8.00
Al	2.19		2.88		2.79	
Al	0.92	6.49	0.62	6.52	0.30	6.24
Ti	0.32		0.32		0.32	
Fe^{3+}	0.21		0.28		0.17	
Fe^{2+}	2.55		3.04		2.77	
Mn	0.05		0.13		0.07	
Mg	2.10		1.62		2.26	
Li	0.34		0.51		0.52	
Ca	0.03	2.04	0.04	0.99	0.13	1.65
Na	0.06		0.05		0.05	
K	1.94		0.90		1.46	
Rb	0.01		n.d.		0.01	
OH	1.70		3.77		3.52	

Biotites, numbers of ions on the basis of 24(O, OH, F)

	(4)60-74B		(6)61-71B		(2)64-70B	
Si	5.64	8.00	5.31	8.00	5.76	8.00
Al	2.36		2.69		2.24	
Al	0.79	6.58	0.40	6.44	0.67	6.63
Ti	0.33		0.30		0.28	
Fe^{3+}	-		0.25		0.22	
Fe^{2+}	2.72		2.58		2.72	
Mn	0.07		0.07		0.06	
Mg	2.20		2.21		2.32	
Li	0.47		0.63		0.36	
Ca	0.05	1.71	0.10	1.64	0.05	1.81
Na	0.05		0.06		0.04	
K	1.60		1.47		1.71	
Rb	0.01		0.01		0.01	
OH	2.46		3.39		1.94	

Chlorite analyses:

	(3)50-66C	(8)53-69C	(9)54-68C
SiO_2	29.16	27.44	27.47
TiO_2	1.53	1.04	1.00
Al_2O_3	18.63	18.58	19.42
Fe_2O_3	1.41	1.55	1.16
FeO	26.40	27.25	28.57
MnO	0.58	1.33	1.05
MgO	12.97	10.02	10.06
CaO	0.17	0.78	0.23
Li_2O	0.63	1.05	0.97
Na_2O	0.13	0.10	0.09
K_2O	1.19	0.74	0.53
ZnO	0.07	0.10	0.10
P_2O_5	0.09	0.04	0.03
H_2O^+	6.79	7.08	7.18
H_2O^-	0.90	0.33	0.94
LOI	3.95	4.41	3.95
Total	104.60	101.84	102.75
$O \equiv F$	1.66	1.85	1.66
Total	102.31	99.28	100.46
Be	-	-	-
Cr	150	112	87
Ni	82	61	57
Cu	106	54	27
Zn	548	822	840
Pb	47	118	74

Chlorite analyses:

	(10)56-70C	(11)57-69C	(P)73/517C
SiO_2	28.52	22.80	29.97
TiO_2	1.82	0.22	0.91
Al_2O_3	19.60	21.24	21.14
Fe_2O_3	2.05	1.57	2.43
FeO	29.19	34.34	27.62
MnO	1.23	1.61	1.14
MgO	7.54	5.08	7.70
CaO	0.12	0.04	0.18
Li_2O	0.77	0.83	0.73
Na_2O	0.07	0.07	0.26
K_2O	1.11	0.25	1.02
ZnO	0.18	0.06	0.17
P_2O_5	0.04	0.05	0.08
H_2O^+	4.80	n.d.	n.d.
H_2O^-	0.53	n.d.	n.d.
LOI	6.18	n.d.	n.d.
Total	103.75		
$O \equiv F$	2.60		
Total	100.17		
Be	10	6	6
Cr	42	58	17
Ni	45	153	36
Cu	74	25	21
Zn	1459	515	1391
Pb	159	119	97

Chlorites, Numbers of ions on the basis of 36(O, OH, F).

	(3)50-66C		(8)53-69C		(9)54-68C	
Si	6.23	8.00	6.02	8.00	6.00	8.00
Al	1.77		1.98		2.00	
Al	2.88	13.29	2.78	13.12	2.95	13.10
Ti	0.25		0.17		0.16	
Fe^{3+}	0.22		0.26		0.19	
Fe^{2+}	4.72		5.00		5.22	
Mn	0.11		0.25		0.19	
Mg	4.13		3.27		3.28	
Ca	0.04		0.18		0.05	
Li	0.54		0.93		0.85	
Na	0.05		0.04		0.04	
K	0.32		0.21		0.14	
Zn	0.01		0.02		0.02	
P	0.02		0.01		0.01	
*OH/F	7.51		8.24		7.96	

	(10)56-70C		(11)57-69C		(P)73/517C	
Si	6.34	8.00	5.14	7.94	6.50	8.00
Al	1.66		2.80		1.50	
Al	3.43	13.34	-	10.36	3.85	13.21
Ti	0.30		0.04		0.15	
Fe^{3+}	0.34		0.27		0.39	
Fe^{2+}	5.43		6.48		5.01	
Mn	0.23		0.31		0.21	
Mg	2.50		1.71		2.49	
Ca	0.03		0.01		0.04	
Li	0.69		0.75		0.64	
Na	0.03		0.03		0.11	
K	0.32		0.74		0.28	
Zn	0.03		0.01		0.03	
P	0.01		0.01		0.01	
OH/F	7.91		+11.86		+7.74	

* assuming LOI ≡ F

\+ OH/F calculated by difference.

Muscovite analyses

	(8)53-69M	(9)54-68M	(10)56-70M	(11)57-69M	(12)58-70M
SiO_2	47.12	47.80	49.01	48.70	47.33
TiO_2	0.80	0.78	0.47	0.28	0.15
Al_2O_3	30.62	30.60	31.39	30.32	32.36
Fe_2O_3	1.85	1.67	1.38	1.27	1.64
FeO	1.65	1.38	0.70	2.12	2.06
MnO	0.09	0.08	0.12	0.17	0.18
MgO	1.49	1.41	0.95	1.20	0.73
CaO	0.25	0.19	1.44	0.29	0.17
Li_2O	0.47	0.45	0.28	0.57	0.77
Na_2O	0.68	0.69	0.64	0.52	0.42
K_2O	9.96	10.02	9.61	9.47	9.94
Rb_2O	n.d.	n.d.	0.09	0.16	0.18
P_2O_5	0.09	0.09	0.94	0.12	0.07
H_2O^+	1.17	0.78	1.44	1.53	1.27
H_2O^-	0.48	0.40	0.60	0.45	0.60
LOI	3.53	3.91	3.57	5.45	3.67
Total	100.25	100.25	102.54	102.46	101.36
O ≡ F	1.48	1.64	1.50	2.29	1.54
Total	98.20	97.98	100.47	99.30	99.23
Be	9	13	21	23	18
Sr	n.d.	n.d.	11	1	4
Y	n.d.	n.d.	97	126	143
Zr	n.d.	n.d.	25	-	14
Cr	34	8	10	6	3
Ni	37	30	43	39	45
Cu	22	-	10	4	15
Zn	146	55	311	147	311

Muscovite analyses:

	(7)60-72M	(4)60-74M	(6)61-71M	(P)73/517M
SiO_2	47.41	49.12	46.87	46.52
TiO_2	1.23	0.85	1.25	0.29
Al_2O_3	30.84	29.86	29.15	33.66
Fe_2O_3	2.40	1.17	2.34	2.10
FeO	1.09	1.87	1.47	0.97
MnO	0.04	0.05	0.06	0.07
MgO	1.31	1.58	1.46	0.79
CaO	0.24	0.21	0.51	0.02
Li_2O	0.24	0.19	0.36	0.27
Na_2O	0.61	0.59	0.74	0.62
K_2O	10.07	9.61	9.42	10.02
Rb_2O	0.10	n.d.	n.d.	0.10
P_2O_5	0.07	0.06	0.06	0.04
H_2O^+	1.44	0.67	1.13	0.86
H_2O^-	0.56	0.65	0.81	1.08
LOI	3.08	4.70	3.47	4.04
Total	100.63	101.18	99.10	101.35
O ≡ F	1.29	1.98	1.46	1.70
Total	98.84	98.46	97.09	99.01
Be	14	8	21	12
Sr	11	n.d.	n.d.	-
Y	78	n.d.	n.d.	79
Zr	20	n.d.	n.d.	-
Cr	49	68	51	-
Ni	37	32	37	47
Cu	15	33	10	-
Zn	58	200	84	115

Muscovites, numbers of ions on the basis of 24(O, OH, F)

	(8)53-69M		(9)54-68M		(10)56-70M	
Si	6.74	8.00	6.86	8.00	6.77	8.00
Al	1.26		1.14		1.23	
Al	3.90	5.01	4.04	5.06	3.88	4.52
Ti	0.09		0.08		0.05	
Fe^{3+}	0.21		0.19		0.15	
Fe^{2+}	0.21		0.17		0.08	
Mn	0.01		0.01		0.01	
Mg	0.32		0.31		0.19	
Li	0.27		0.26		0.16	
Ca	0.04	2.05	0.03	2.05	0.21	2.08
Na	0.19		0.19		0.17	
K	1.82		1.83		1.69	
Rb	n.d.		-		0.01	
OH	1.12		0.75		1.33	

	(11)57-69M		(12)58-70M		(7)60-72M	
Si	6.87	8.00	6.68	8.00	6.70	8.00
Al	1.13		1.32		1.30	
Al	3.91	4.92	4.07	5.13	3.84	4.79
Ti	0.03		0.02		0.13	
Fe^{3+}	0.14		0.19		0.27	
Fe^{2+}	0.25		0.24		0.13	
Mn	0.02		0.02		0.00	
Mg	0.25		0.15		0.28	
Li	0.32		0.44		0.14	
Ca	0.04	1.89	0.03	1.95	0.04	2.04
Na	0.14		0.11		0.17	
K	1.70		1.79		1.82	
Rb	0.01		0.02		0.01	
OH	1.44		1.20		1.36	

Muscovites, numbers of ions on the basis of 24(O, OH, F)

	(4)60-74M		(6)61-71M		(P)73/517M	
Si	7.05	8.00	6.80	8.00	6.64	8.00
Al	0.95		1.20		1.36	
Al	4.10	5.00	4.99	6.12	4.30	5.03
Ti	0.09		0.14		0.03	
Fe^{3+}	0.13		0.27		0.24	
Fe^{2+}	0.22		0.18		0.12	
Mn	0.01		0.01		0.01	
Mg	0.34		0.32		0.17	
Li	0.11		0.21		0.16	
Ca	0.03	1.95	0.08	2.03	0.00	1.99
Na	0.16		0.21		0.17	
K	1.76		1.74		1.82	
Rb	n.d.		n.d.		0.01	
OH	0.64		1.09		0.82	

Feldspar/Quartz analyses:

	(3)50-66F	(5)51-71F	(8)53-69F	(9)54-68F
CaO	0.44	0.88	0.89	0.43
Na_2O	3.06	3.37	3.63	3.42
K_2O	4.58	3.79	2.96	3.75
Li	31	49	67	27
Rb	198	177	187	215
Be	7	3	4	5
Sr	246	134	123	102
Y	15	10	13	14
Zr	61	56	47	49
Cu	12	11	13	10
Zn	8	10	5	8
Pb	27	29	26	35
K/Rb	192	145	131	145
Ca/Sr	13	47	51	30
K/Pb	1204	1036	808	760

	(1)55-75F	(10)56-70F	(11)57-69F	(12)58-70F
CaO	2.24	0.52	0.33	0.37
Na_2O	3.82	3.39	3.84	4.36
K_2O	3.24	3.35	2.96	2.51
Li	25	33	30	36
Rb	106	189	245	291
Be	5	4	7	13
Sr	285	121	23	33
Y	4	11	17	21
Zr	74	45	14	13
Cu	10	11	11	11
Zn	5	7	-	5
Pb	33	24	19	14
K/Rb	253	147	100	72
Ca/Sr	87	31	101	80
K/Pb	697	991	1106	1272

Feldspar/Quartz analyses:

	(7)60-72F	(4)60-74F	(6)61-71F	(2)64-70F	(P)73/517F
CaO	1.11	0.81	0.99	1.56	0.26
Na_2O	3.55	3.08	3.62	3.42	2.73
K_2O	4.00	4.18	3.94	3.61	3.84
Li	39	48	64	33	21
Rb	208	187	225	156	237
Be	5	5	6	7	2
Sr	182	137	148	182	21
Y	13	9	14	8	13
Zr	58	48	52	60	1
Cu	10	12	11	11	11
Zn	4	5	6	4	-
Pb	36	32	27	34	41
K/Rb	160	186	145	192	134
Ca/Sr	61	31	47	61	88
K/Pb	789	927	1036	754	665

Cr and Ni below detection limit in all analyses.

APPENDIX 8

Chemical analyses of sulphides and crude ores.

All sample numbers are preceded by a letter indicating the type of material:
S, sphalerite; G, galena; C, chalcopyrite; A, arsenopyrite; P, pyrrhotite; O, crude ore.

Numbers heading columns refer to numbers on Figures 98-104.

Localities are given in appendix 10, E.

	1	2	3	4
	S.74/892b	S.74/891a	S.74/889	S.73/518Bd
Zn	64.98	67.91	56.45	49.25
Fe	2.22	1.68	6.48	6.18
Cd	0.44	0.41	0.80	0.18
Mn	13	16	55	50
Ni	6	3	-	25
Co	100	102	94	83
Pb	0.05	0.01	0.03	3.41
Cu	0.09	0.03	0.09	0.05
Ag	20	10	21	620
As	-	-	-	0.15
insol.	1.22	0.03	0.56	18.60
100-total	30.54	29.92	35.58	22.12
Recalculated				
Zn	65.78	67.93	56.77	60.50
Fe	2.25	1.68	6.52	7.59
Cd	0.45	0.41	0.80	0.22
Mn	13	16	55	61
Ni	6	3	-	31
Co	101	102	95	102
Pb	0.51	0.01	0.03	4.19
Cu	0.09	0.03	0.09	0.06
Ag	20	10	21	762
As	-	-	-	0.18
100-total	30.92	29.93	35.78	27.17
Pb/Ag	255	10	14	55
Zn/Cd	148	165	71	273
Zn/Fe	29	40	9	8
Ni/Co	0.06	0.03	-	0.30

	5	6	7	8
	S.73/518Bc	S.73/518Ah	S.74/645	S.74/783
Zn	49.37	46.20	65.72	58.68
Fe	9.87	5.76	1.86	3.97
Cd	0.13	0.14	0.38	0.22
Mn	315	128	33	49
Ni	-	28	-	-
Co	118	92	8	36
Pb	8.38	3.42	0.05	0.12
Cu	0.03	0.03	0.10	0.08
Ag	558	83	169	57
As	-	-	-	-
insol.	0.83	17.20	0.57	0.12
100-total	31.32	27.22	31.30	36.80
Recalculated				
Zn	49.76	55.76	66.10	58.75
Fe	9.95	6.95	1.87	3.97
Cd	0.13	0.17	0.38	0.22
Mn	318	154	33	49
Ni	-	34	-	-
Co	119	111	8	36
Pb	8.45	4.13	0.05	0.12
Cu	0.03	0.04	0.10	0.08
Ag	562	100	170	57
As	-	-	-	-
100-total	31.57	32.85	31.48	36.84
Pb/Ag	150	413	3	21
Zn/Cd	380	330	173	267
Zn/Fe	5	8	35	15
Ni/Co	-	0.31	-	-

	9 S.74/639g	10 S.74/644d	11 S.72/090	12 S.72/085
Zn	67.23	57.17	62.01	62.61
Fe	1.45	5.72	3.09	0.93
Cd	0.24	0.73	0.30	0.41
Mn	17	166	43	6
Ni	2	6	8	6
Co	12	23	26	61
Pb	0.02	0.52	0.05	0.31
Cu	0.11	0.20	0.05	0.10
Ag	71	1357	78	21
As	-	0.10	-	-
insol.	2.46	-	3.57	4.68
100-total	28.48	35.49	30.92	30.94
Recalculated				
Zn	68.93	57.17	64.30	65.68
Fe	1.49	5.72	3.20	0.98
Cd	0.25	0.73	0.31	0.43
Mn	17	166	45	6
Ni	2	6	8	6
Co	12	23	27	64
Pb	0.02	0.52	0.05	0.33
Cu	0.11	0.20	0.05	0.10
Ag	73	1357	81	22
As	-	0.10	-	-
100-total	29.20	35.49	32.06	32.46
Pb/Ag	3	4	6	150
Zn/Cd	280	78	207	153
Zn/Fe	46	10	20	67
Ni/Co	0.17	0.26	0.30	0.09

	1	2	3	4
	G.72/017	G.74/891d	G.74/889	G.73/516
Pb	86.58	85.25	88.70	87.24
Zn	9	27	37	1.13
Cu	69	-	22	24
Ag	19	18	17	236
Mn	2	-	-	6
Cd	-	-	-	24
Cr	45	-	-	-
Fe	370	-	-	570
insol.	-	-	-	-
Pb/Ag	45568	47361	52176	3697
Zn/Cd	-	-	-	470

	5	6	7	8
	G.72/012	G.74/639(8)	G.74/644(4)	G.74/1167
Pb	65.11	88.08	90.41	90.50
Zn	0.19	193	0.30	36
Cu	16	81	47	0.07
Ag	327	266	293	48
Mn	-	-	-	-
Cd	4	8	36	-
Cr	39	30	-	-
Fe	160	80	260	100
insol.	-	-	-	-
Pb/Ag	1991	3311	3085	18854
Zn/Cd	475	24	83	-

N.B. As, Ni, Co lower than sensitivity in all samples.

	1	2	3	4
	C.74/892c	C.74/891b	C.74/639d	C.74/633a
Cu	32.41	40.89	44.84	36.12
Fe	27.17	29.47	20.95	29.59
Ni	0.13	324	311	86
Co	235	61	114	-
Zn	0.15	205	0.78	206
Pb	371	218	0.28	830
Cd	18	4	36	4
Ag	57	197	163	171
As	0.06	-	0.40	0.08
Cr	15	10	20	-
Mn	3	26	3	20
insol.	2.39	2.93	9.17	6.81
Recalculated				
Cu	33.20	42.12	49.37	38.75
Fe	27.84	30.35	23.07	31.75
Ni	0.13	334	342	92
Co	241	63	126	-
Zn	0.15	211	0.86	221
Pb	380	225	0.31	891
Cd	18	4	40	4
Ag	58	203	179	183
As	0.06	-	0.44	0.09
Cr	15	10	22	-
Mn	3	27	3	21
Pb/Ag	6.55	1.11	17.32	4.87
Zn/Cd	83	53	215	55
Ni/Co	5.53	5.31	2.73	16

	5	6	7
	C.74/1167	C.74/1176	C.74/004d
Cu	29.06	41.71	21.17
Fe	29.64	29.01	15.98
Ni	50	20	0.25
Co	6	9	239
Zn	670	102	670
Pb	417	0.13	66
Cd	5	-	12
Ag	357	106	102
As	0.09	-	0.41
Cr	-	10	18
Mn	10	-	31
insol.	3.53	2.56	4.25
Recalculated			
Cu	30.12	42.80	22.11
Fe	30.72	29.77	16.68
Ni	52	21	0.26
Co	6	9	250
Zn	695	105	700
Pb	432	0.13	69
Cd	5	-	13
Ag	370	109	106
As	0.09	-	0.43
Cr	-	10	19
Mn	10	-	32
Pb/Ag	1.17	11.93	0.65
Zn/Cd	139	-	54
Ni/Co	8.33	2.22	10.46

	A.72/005	A.73/515	P.74/004
Fe	31.23	20.45	43.66
As	43.80	30.80	0.05
Ni	19	17	3.82
Co	147	60	974
Pb	396	798	191
Zn	166	143	60
Mn	-	61	76
Cd	2	-	7
Ag	7	26	8
Cr	-	-	179
Cu	3	87	832
insol.	5.72	30.95	6.24
Recalculated			
Fe	33.12	29.62	46.57
As	46.46	44.61	0.05
Ni	20	25	4.07
Co	156	87	0.10
Pb	420	0.12	204
Zn	176	207	64
Mn	-	88	81
Cd	2	-	7
Ag	7	38	8
Cr	-	-	191
Cu	3	126	887

	0.73/513	0.74/004d	0.73/507a	0.73/507b
Cu	0.88	1.00	0.33	0.39
Pb	100	81	5	25
Zn	96	88	125	144
Fe	26.20	27.90	1.90	9.30
Mn	309	270	17	17
Cd	-	4	1	4
Ag	8	7	1	4
As	100	-	50	0.03
Ni	2.08	2.61	6	177
Co	729	0.11	140	0.12
Cr	842	609	-	-
insol.	40.10	24.12	94.00	80.80
Zn/Cd	-	-	-	-
Co/Ni	0.04	0.04	23.33	6.78

	0.72/031	0.74/639b	0.74/1167
Cu	265	12.45	7.65
Pb	74	2.82	424
Zn	11.05	0.62	714
Fe	3.70	27.70	15.30
Mn	1.36	165	3
Cd	821	10	4
Ag	8	149	70
As	100	0.34	0.36
Ni	94	257	900
Co	68	87	459
Cr	-	-	4
insol.	*47.10	15.30	58.80
Zn/Cd	135	-	-
Co/Ni	0.72	0.34	0.51

* Carbonate accounts for low quantities of insoluble residue

APPENDIX 9

Chemical analyses of wallrocks adjacent to hydrothermal vein deposits.

Sample numbers have a format e.g. 72/W. 428 but are reduced for clarity in these tables. Complete sample numbers are provided in appendix 10, D.

	428	428A	507A	507B
SiO_2	79.10	76.90	82.80	74.50
TiO_2	0.63	0.54	0.19	0.25
Al_2O_3	9.52	11.18	9.11	12.77
Fe_2O_3	0.67	0.32	0.48	0.40
MnO	0.01	0.01	0.02	0.01
MgO	0.21	0.27	0.29	0.40
CaO	0.27	0.26	0.19	0.21
Na_2O	0.09	0.05	0.15	2.54
K_2O	7.42	8.04	4.79	5.57
P_2O_5	0.03	0.06	0.01	0.03
H_2O	0.91	0.68	1.24	1.28
LOI	0.44	0.77	0.45	0.48
Total	99.30	99.08	99.72	98.44
Li	90	100	158	65
Rb	223	117	325	315
Be	2	2	4	2
Sr	57	77	-	58
Y	26	-	178	76
Zr	239	141	97	132
Cr	346	176	14	28
Co	130	90	80	77
Ni	34	20	14	14
Cu	37	31	13	14
Zn	1313	1390	32	27
Pb	1699	6475	19	24

	085	518A	519A
SiO_2	87.70	78.90	76.40
TiO_2	0.05	0.50	0.62
Al_2O_3	5.42	5.77	9.72
Fe_2O_3	1.37	1.01	2.94
MnO	0.02	0.05	0.05
MgO	0.45	2.29	2.41
CaO	0.09	3.09	1.47
Na_2O	0.09	0.06	0.33
K_2O	1.72	3.06	4.24
P_2O_5	-	0.12	0.07
H_2O	0.78	1.04	2.00
LOI	3.13	4.84	1.63
Total	100.82	100.73	101.88
Li	50	190	118
Rb	50	131	139
Be	2	2	6
Sr	11	15	27
Y	-	8	8
Zr	53	205	205
Cr	100	176	289
Co	80	55	75
Ni	60	100	100
Cu	145	29	32
Zn	187	1525	103
Pb	543	156	762

APPENDIX 10

Localities of samples used in petrological and geochemical analysis

The eight figure National Grid references contain 100 km grid figures as the first and fifth integers, e.g. 2 xxx 5 xxx.

Most granite sample numbers have the prefix 73/G.- unless otherwise denoted.

Most greywacke, shale or hornfels sample numbers have the prefix 74/H.- unless otherwise denoted.

A. Granite sample localities.

73/G.	49-65	24915651	73/G.	57-65	25715647
	49-67	24915668		57-69	25705692
	49-69	24905690		57-71	25705710
	49-71	24925711		57-73	25615769
	50-66	25015661		57-75	25675751
	50-68	25005681		58-66	25805660
	50-70	25005700		58-68	25745684
	50-72	25005720		58-70	25795701
	51-65	25125651		58-72	25805720
	51-67	25095670		58-74	25805740
	51-69	25105690		58-76	25775760
	51-71	25105710		59-67	25895671
	51-73	25105730		59-69	25915689
	52-64	25195645		59-71	25905710
	52-66	25205660		59-75	25905750
	52-68	25215682		60-66	26005662
	52-70	25205701		60-68	26015679
	52-72	25205720		60-70	25955699
	52-74	25205740		60-72	25955718
	53-65	25365656		60-74	26005740
	53-67	25285669		60-76	26005760
	53-69	25305690		61-67	26155675
	53-71	25345707		61-69	26115689
	53-73	25295731		61-71	26125710
	54-64	25405641		61-73	26115729
	54-66	25425660		61-75	26095753
	54-68	25405680		62-68	26205680
	54-70	25365699		62-70	26235701
	54-72	25385720		62-72	26205717
	54-74	25445739		62-74	26225744
	55-65	25495648		62-76	26225759
	55-69	25505690		63-69	26305690
	55-71	25525710		63-71	26315712
	55-73	25535736		63-73	26315731
	55-75	25485751		63-75	26315751
	56-68	25635680		64-70	26395698
	56-70	25605701		64-72	26425721
	56-72	25605720		64-74	26425740
	56-74	25595741	72/G.	435	24805695
	56-76	25615759	72/G.	436	24805690
			74/G.	826	25805649

B. Greywacke, shale and hornfels sample localities.

74/H.	44-66	24415663	74/H.	52-76	25205760
	44-68	24425680		53-59	25285592
	45-65	24505650		53-61	25325610
	45-67	24515671		53-63	25305630
	45-69	24515689		53-75	25315752
	45-71	24525708		53-77	25285771
	46-64	24605640		54-60	25395600
	46-66	24615660		54-62	25405618
	46-68	24605680		54-76	25415762
	46-70	24625701		55-61	25505610
	47-61	24685610		55-63	25475630
	47-63	24705630		55-77	25525769
	47-65	24705650		56-62	25595622
	47-67	24705671		56-64	25665643
	47-69	24695688		56-78	25605780
	47-71	24695709		57-61	25695610
	47-73	24705730		57-63	25705630
	48-58	24805579		57-77	25705774
	48-62	24825621		57-79	25705790
	48-64	24795639		58-62	25795619
	48-66	24795659		58-64	25785640
	48-68	24795679		58-78	25805780
	48-70	24805700		58-80	25805800
	48-72	24785719		59-63	25905630
	48-74	24805740		59-65	25905650
	49-59	24905589		59-77	25935772
	49-61	24845604		59-79	25895793
	49-73	24905729		59-81	25905811
	49-75	24905750		60-64	26065641
	50-58	24965579		60-78	62045783
	50-60	25005598		60-80	26005800
	50-62	25075618		61-63	26115631
	50-64	25035637		61-65	26105647
	50-74	25015741		61-77	26135769
	50-76	25005758		61-79	26105790
	51-59	25065588		62-64	26155635
	51-61	25095611		62-66	20245659
	51-63	25155629		62-78	26205782
	51-75	25105751		62-80	26165800
	52-60	25235600		63-65	26305650
74/H.	52-62	25205621		63-67	26355670

74/H.	63-77	26285771	72/H.	465	24505680
	63-79	26305790		468	24555685
	64-66	26405659			
	64-68	26405681			
	64-76	26455763			
	64-78	26415780			
	65-67	26505669			
	65-69	26515690			
	65-71	26535710			
	65-73	26505730			
	65-75	26535751			
	65-77	26525769			
	66-68	26585680			
	66-70	26635701			
	66-72	26605719			
	66-74	26605741			
	66-76	26615759			
	67-69	26705690			
	67-71	26695710			
	67-73	26705730			
	67-75	26695749			
72/H.	290	24405650			
	305	24455656			
	437	24805685			
	439	24805680			
	441	24755680			
	443	24755685			
	445	24755690			
	446	24655680			
	448	24705680			
	452	24705685			
	453	24745695			
	454	24705695			
	455	24655695			
	456	24605695			
	458	24655690			
	462	24655685			
	463	24605680			
	464	24555680			

C. Minor intrusive igneous sample localities

72/I. 004A	metadiorite sill, Talnotry.	24785703
72/I. 004B	metadiorite sill, Talnotry.	24785703
72/I. 140	altered lamprophyre, Cumloden.	24165676
72/I. 220B	kersantite, Grey Mare's Tail Burn.	24885732
72/I. 220A	kersantite, Grey Mare's Tail Burn.	24885732
72/I. 221	albitized kersantite (from above).	24875732
72/I. 375	kersantite, Drumlawhinnie Loch.	24645698
74/I. 679	ultrabasic intrusion, Clanery Hill.	24875630
74/I. 762	porphyritic microdiorite, Glen-quicken.	25165586
74/I. 854	spessartite, Drumcleigh.	24585720
74/I.1196	spessartite, Waterside.	26085810

D. Hydrothermal vein wallrock sample localities

72/W. 085	Culcronchie, upper vein.	25115638
72/W. 428	Bargaly, N-S. vein wallrock	24665682
72/W. 428A	Bargaly, N-S. vein breccia.	24665682
73/W. 507A	Orchars vein.	25785730
73/W. 507B	Orchars vein.	25785730
73/W. 518A	Wood of Cree vein.	23875695
73/W. 519A	Dallash vein.	24715693

E. Sample localities of hydrothermal vein material.

Sphalerites

1. S.74/892b, West Blackcraig, tip.
2. S.74/891a, East Blackcraig, tip below engine shaft.
3. S.74/889, Silver Rig, tip by main shaft.
4. S.73/518Bd, Coldstream Burn, tip.
5. S.73/518Bc, Coldstream Burn, tip.
6. S.73/518Ah, Wood of Cree, vein in main level.
7. S.74/645, Chain Burn, tip by shaft.
8. S.74/783, Meikle Dennan, tips at entrance of lower level.
9. S.74/639g, Pibble, tips by upper workings.
10. S.74/644d, Dromore, vein hanging wall.
11. S.72/090, Dromore, tip.
12. S.72/085, Culcronchie, upper vein.

Galenas

1. G.72/017, West Blackcraig, tip.
2. G.74/891d, East Blackcraig, tip below engine shaft.
3. G.74/889, Silver Rig, tip by main shaft.
4. G.73/516, Bargaly, tip at entrance to level.
5. G.72/012, Bargaly, tip at entrance to level.
6. G.74/639(8), Pibble, tips by upper workings.
7. G.74/644(4), Dromore, vein hanging wall.
8. G.74/1167, Drumruck, tip.

Chalcopyrites.

1. C.74/892c, West Blackcraig, tip.
2. C.74/891b, East Blackcraig, tip below engine shaft.
3. C.74/639d, Pibble, tips by upper workings.
4. C.74/633a, Pibble, tip by lower shaft.
5. C.74/1167, Drumruck, tip.
6. C.74/1176, Culcronchie, tip at middle vein.
7. C.74/004d, Talnotry (Ni-Co), tip.

Arsenopyrites.

A.72/005, Talnotry, Palnure Burn tip.

A.72/515, Talnotry, Glen of the Bar tip.

Pyrrhotite

p.74/004, Talnotry (Ni-Co), tip.

Crude ores

0.73/513, Talnotry (Ni-Co), upper working vein margin.

0.74/004d, Talnotry (Ni-Co), centre of vein.

0.73/507a, Orchars, vein.

0.73/507b, Orchars, vein.

0.72/031, Tonderghie, vein.

0.74/639b, Pibble, tips by upper workings.

0.74/1167, Culcronchie, tip at middle vein.

Table 1. Various average greywacke analyses.

	1	2	3	4	5
SiO_2	67.89	64.7	61.88	60.3	65.1
TiO_2	0.65	0.5	0.82	0.66	0.80
Al_2O_3	11.60	14.8	12.40	11.8	14.2
Fe_2O_3	0.47	1.5	6.27	4.7	6.0
FeO	4.24	3.9	-	-	-
MnO	0.08	0.1	0.03	0.03	0.02
MgO	3.66	2.2	4.71	4.2	4.5
CaO	2.46	3.1	5.41	4.7	2.2
Na_2O	2.39	3.2	2.18	2.6	2.6
K_2O	2.09	1.9	2.05	2.0	2.1
P_2O_5	0.16	0.2	0.15	0.14	0.15
Li	92	30	-	-	-
Rb	75	120	82	66	110
Be	2	3	-	-	-
Sr	279	450	168	171	282
Y	15	30	26	23	29
Zr	272	140	299	277	342
Ni	73	50	-	-	-
Cu	26	40	20	17	19
Zn	61	50	71	55	71
Pb	24	15	20	-	-
Cr	181	140	-	-	-
Na_2O/K_2O	1.15		1.06	1.3	1.12
Al_2O_3/Na_2O	4.9		5.7	4.5	5.5

1. Mean of total data set (89) of Silurian greywackes analysed in this study.
2. Average greywacke major element analysis from Pettijohn (1957) and trace element analysis from Taylor (1965).
3. Average Silurian greywacke from Alsayegh (1971).
4. Average greywacke from the Kilfillan Formation from the Whithorn - Glenluce area (Alsayegh, 1971).
5. Average greywacke from the Garheugh Formation from the Whithorn-Glenluce area (Alsayegh, 1971).

\- indicates no data.

Table 2. Means ($\bar{x}$) and standard deviations (s) of greywacke analyses.

	lithic group (43)		basic group (19)	
	$\bar{x}$	s	$\bar{x}$	s
SiO_2	66.81	2.57	70.11	2.90
TiO_2	0.70	0.09	0.69	0.11
Al_2O_3	12.60	1.13	10.70	0.99
Fe_2O_3	0.50	0.44	0.22	0.21
FeO	4.66	0.79	4.49	0.57
MnO	0.08	0.02	0.07	0.02
MgO	3.95	0.68	4.06	0.80
CaO	2.12	1.37	2.33	0.73
Na_2O	2.48	0.41	1.95	0.72
K_2O	2.44	0.58	1.85	0.53
P_2O_5	0.17	0.03	0.13	0.02
Li	98	37	115	43
Rb	85	21	71	26
Be	2	2	2	1
Sr	280	97	213	49
Y	17	3	15	3
Zr	285	41	280	55
Ni	78	17	87	24
Cu	25	2	27	2
Zn	65	19	57	9
Pb	25	9	23	4
Cr	166	52	315	94
K/Rb	238		216	
Ti/Cr	26		13	
Mg/Ni	304		280	
Fe/Cr	219		190	

Figures in brackets refer to the number of samples in each group.

Table 3. Means and standard deviations of greywacke analyses.

	feldspathic group (13)		silicic group (14)	
	$\bar{x}$	s	$\bar{x}$	s
SiO_2	63.39	3.35	71.09	6.06
TiO_2	0.77	0.09	0.48	0.07
Al_2O_3	14.58	1.05	9.60	1.40
Fe_2O_3	0.95	0.48	0.37	0.24
FeO	4.53	0.82	3.44	0.52
MnO	0.09	0.01	0.07	0.01
MgO	3.81	1.22	2.90	0.91
CaO	3.10	1.13	3.58	2.61
Na_2O	3.36	0.68	2.00	0.59
K_2O	2.31	0.63	1.38	0.48
P_2O_5	0.20	0.03	0.12	0.03
Li	76	13	62	16
Rb	72	18	54	19
Be	2	1	2	1
Sr	501	92	160	76
Y	14	2	14	2
Zr	264	34	230	44
Ni	69	16	44	14
Cu	28	4	25	3
Zn	69	9	48	12
Pb	23	8	27	18
Cr	126	65	103	27
K/Rb	266		212	
Ti/Cr	37		28	
Mg/Ni	330		395	
Fe/Cr	280		260	

Table 4. Means and standard deviations of shale and contaminated sample analyses.

	shale (12)			contaminated samples (2)	
	$\bar{x}$	s	*	$\bar{x}$	s
SiO_2	60.50	3.73	58.10	60.85	5.59
TiO_2	0.70	0.11	0.65	0.58	0.09
Al_2O_3	16.02	1.46	15.40	15.89	2.57
Fe_2O_5	0.87	0.67	4.02	0.94	0.35
FeO	5.83	0.87	2.45	5.00	2.72
MnO	0.18	0.12	-	0.08	0.00
MgO	5.03	0.96	2.44	4.84	2.23
CaO	2.01	1.53	3.11	0.90	0.68
Na_2O	1.75	0.39	1.30	2.22	0.63
K_2O	3.46	0.78	3.24	3.19	0.10
P_2O_5	0.12	0.03	0.17	0.17	0.01
Li	156	44	60	102	36
Rb	141	27	60	115	20
Be	2	1	2	4	2
Sr	198	72	300	107	54
Y	21	4	25	21	1
Zr	189	32	160	210	43
Ni	111	31	70	132	81
Cu	32	4	50	32	6
Zn	96	17	100	527	41
Pb	32	4	20	212	16
Cr	183	41	100	178	106

*average shale major element analysis from Pettijohn (1957) and trace element analysis from Taylor (1965).

Table 5. The Penkiln Burn traverse.

N.B. All contacts are stratigraphical unless otherwise stated in tables 5-7.

		approximate true thickness in metres
	Old Sand Pit, Hawk Hill (24305687) map 1.	
20.	Craignell greywacke, graded, inverted younging north.	
	UPPER BOUNDARY THRUST (of the Talnotry thrust zone)	
19.	Upper Birkhill lithology dark grey laminated mudstones.	45
18.	Birkhill lithology black pyritous mudstone, highly sheared and quartz veined.	25
	FAULT	
17.	Craignell greywacke, drag folded and highly quartz veined.	10
	FAULT	
16.	Upper Birkhill lithology light and dark grey laminated mudstones.	10
	FAULT	
15.	Craignell greywacke, graded bedding indicates northward younging direction, intensively quartz veined.	20
	FAULT	
14.	Upper Birkhill lithology grey laminated mudstones.	10
	FAULT	
13.	Hartfell black mudstone with graptolites including <u>Orthograptus</u> cf. <u>calcaratus</u> (Lapworth) and Climacograptids. Sheared black pyritous mudstones with 5 cm thick massive mudstone bands. Subordinate non-sheared barren grey mudstone band. Highly quartz veined. Basal black mudstone, brecciated and quartz veined adjacent to fault.	50
	FAULT	
12.	Craignell greywacke wedge.	2
	FAULT	

11.	Hartfell lithology dark grey-black mudstone, brecciated near faults.	120
	FAULT	
10.	Upper Birkhill lithology dark and light grey laminated shales.	90
	FAULT	
9.	Hartfell lithology black pyritous mudstone, highly sheared.	140
	FAULT (lamprophyre dyke)	
8.	Craignell greywacke, graded bedding, inverted younging north.	20
	FAULT	
7.	Upper Birkhill lithology grey-black laminated mudstones with intraformational mud flake pseudoconglomerate.	100
	FAULT	
6.	Craignell greywacke, graded bedding, younging north.	110
5.	Upper Birkhill lithology sheared dark grey-black pyritous mudstones and light grey fine grained greywacke bands.	30
	FAULT	
4.	Craignell greywacke, graded bedding, younging north.	120
3.	Upper Birkhill lithology dark and light grey laminated mudstone.	75
	FAULT	
2.	Craignell greywacke.	85
1.	Upper Birkhill lithology dark grey laminated mudstone.	
	Minnigaff Church (24105666)	

Table 6. The Grey Mare's Tail Burn traverse.

		approximate true thickness in metres.
	Poultrybuie Burn (24905729) map 2.	
9.	Craignell greywacke.	
	UPPER BOUNDARY THRUST (of the Talnotry Thrust zone)	
8.	Grey mudstones and shales.	275
	FAULT	
7.	Hartfell lithology, sooty, graphitic black mudstones with 2-3 cm blocky or platey bands with shaley partings.	25
	THRUST	
6.	Craignell greywacke, upper surfaces adjacent to thrust plane slickensided parallel to the direction of dip.	25
	FAULT	
5.	Lower Birkhill lithology grey-black mudstones.	20
	FAULT	
4.	Craignell greywacke.	15
	FAULT	
3.	Birkhill lithology black mudstones.	15
	FAULT	
2.	Hartfell Barren Grey Mudstone lithology grey-green shales.	200
	TALNOTRY THRUST	
1.	Craignell greywackes containing minor thrusts.	
	Lower Waterfall, Grey Mare's Tail Burn (24785707).	

Table 7. The Blairbuies Hill traverse.

	Blairbuies Burn (24795670) map 1.	approximate true thickness in metres.
31.	Craignell greywacke, basic facies.	
30.	Birkhill lithology black mudstone, crushed brecciated and silicified at base.	2
	UPPER BOUNDARY THRUST (of the Blairbuies thrust zone).	
29.	Craignell greywacke.	50
	FAULT	
	thin band of crushed black mudstone.	
28.	Craignell greywacke.	35
	FAULT	
27.	Hartfell lithology pyritous black mudstone.	12
	FAULT	
	thin wedge of greywacke.	
26.	Hartfell lithology pyritous black mudstone.	10
	FAULT	
25.	Craignell greywacke.	12
	FAULT	
24.	Hartfell lithology black mudstone, at base adjacent to fault highly quartz veined.	10
	FAULT	
23.	Craignell greywacke.	12
	FAULT	
	crushed band of black mudstone.	
22.	Craignell greywacke.	50
	FAULT	
21.	Black mudstone.	30
	FAULT	
	thin band of greywacke.	

20.	Craignell greywacke.	25
	FAULT	
	quartz veined black mudstone band.	
19.	Craignell greywacke.	25
	FAULT	
	thin black mudstone band.	
18.	Craignell greywacke, brecciated.	12
	FAULT	
17.	Upper Birkhill lithology dark grey laminated mudstone.	10
	FAULT	
16.	Craignell greywacke.	30
	FAULTS	
	quartz veins with pyrite.	
15.	Black mudstone.	30
	FAULT	
	band of greywacke.	
14.	Black mudstone.	30
	FAULT	
13.	Lower Birkhill lithology blocky black mudstone.	25
	FAULT	
12.	Upper Hartfell lithology altered black and grey mudstones. Black mudstones dense and pyritous. Grey mudstones highly quartz veined.	15
	FAULT	
11.	Craignell greywacke.	70
	FAULT	
10.	Black mudstone.	10
	FAULT	
	thin band of greywacke.	

9.	Lower Birkhill lithology black rusty weathering mudstone containing deformed pyritized graptolite casts.	25
	FAULT	
8.	Craignell greywacke with graded bedding younging north.	15
	FAULT	
	crushed thin black mudstone band.	
7.	Craignell greywacke.	25
	FAULTS	
	crushed thin black mudstone bands.	
6.	Craignell greywacke.	5
	FAULTS	
	crushed thin black mudstone bands.	
5.	Craignell greywacke.	3
	FAULTS	
	crushed thin black mudstone bands.	
4.	Craignell greywacke, graded bedding, younging north.	5
3.	Upper Birkhill lithology dark grey-black mudstone.	10
	FAULT	
	quartz veins containing chalcopyrite and bornite.	
2.	Upper Birkhill lithology black mudstone.	3
	FAULT	
1.	Craignell greywacke.	

Cairnsmore Burn (24785654).

STAGE	ZONE
	turriculatus
FRONIAN	
	sedgwickii
	convolutus
IDWIAN	
	gregarius
	vesiculosus
	atavus
RHUDDANIAN	
	acuminatus
	persculptus
HIRNANTIAN	
	anceps
RAWTHEYAN	
CAUTLEYAN	
	complanatus
PUSGILLIAN	
	linearis
ONNIAN	
ACTONIAN	
	clingani
MARSHBROOKIAN	
	wilsoni
LONGVILLIAN	
SOUDLEYAN	
	gracilis

Table 8. The Moffat shales sequence at Dobb's Linn after Lapworth, 1878; Walton 1965; Toghill, 1968.

LITHOLOGY	DIVISION
Barren well-bedded grey mudstones with thin seams of black mudstone	UPPER BIRKHILL
Hard black mudstones with occasional softer bands	LOWER BIRKHILL
Pale grey or greenish grey mudstone with subordinate black mudstone bands.	UPPER HARTFELL
Pyritous, rusty weathering black platey mudstones, grey and cherty towards the base.	LOWER HARTFELL
black shales and cherts	GLENKILN

Table 9. Statistics of major oxide and trace element data of the granite samples (n = 76)

	min.	max.	$\bar{x}$	s
SiO_2	68.77	75.78	72.95	1.39
TiO_2	0.12	0.59	0.28	0.09
Al_2O_3	13.20	16.08	14.34	0.50
Fe_2O_3	0.00	2.16	0.46	0.47
FeO	0.07	2.30	1.25	0.42
MnO	0.03	0.07	0.05	0.01
MgO	0.03	1.31	0.58	0.24
CaO	0.18	1.97	0.80	0.38
Na_2O	2.64	4.97	3.31	0.51
K_2O	3.69	5.99	5.21	0.39
P_2O_5	0.05	0.21	0.12	0.03
Li	106	412	262	62
Rb	215	512	299	40
Be	0	17	6	3
Sr	26	308	166	50
Ba	9	1044	632	149
Y	12	40	18	3
La	5	79	37	13
Ce	2	148	85	28
Nd	5	92	42	19
Zr	20	253	146	41
Ni	0	40	20	9
Cu	8	15	9	1
Zn	16	74	39	8
Pb	15	41	31	4

Table 10. Comparison of average Fleet analysis with average low Ca granites and acid magmatic rocks associated with rare metal mineralization.

	1	2		3	4
Li	40	260	SiO_2	73.38 ± 1.39	72.95
Be	3	6	TiO_2	0.16 ± 0.10	0.28
Na	25800	24500	Al_2O_3	13.97 ± 1.07	14.34
Mg	1600	3500	Fe_2O_3	0.80 ± 0.47	0.46
Al	72000	75900	FeO	1.10 ± 0.47	1.25
Si	347000	340800	MnO	0.05 ± 0.04	0.05
P	600	520	MgO	0.47 ± 0.56	0.58
K	42000	43250	CaO	0.75 ± 0.41	0.80
Ca	5100	5700	Na_2O	3.20 ± 0.61	3.31
Ti	1200	1700	K_2O	4.69 ± 0.68	5.21
Mn	390	390			
Fe	14200	13050	Li	400 ± 200	262
Ni	5	20	Rb	580 ± 200	299
Cu	10	9	Be	13 ± 6	6
Zn	39	39			
Rb	170	300			
Sr	100	170			
Y	40	18			
Zr	175	145			
Ba	840	630			
La	55	40			
Ce	92	85			
Nd	37	42			
Pb	19	31			

1. Average low Ca granite in ppm from Turekian and Wedepohl (1961).
2. Average Fleet granite in ppm (n = 76).
3. Range in composition for acid magmatic rocks associated with rare metal mineralization (Tischendorf, 1974).
4. Average Fleet granite.

Table 11. Statistics of major oxide and trace element data from the granite clusters.

	cluster 1 (10)		cluster 2 (48)	
	$\bar{x}$	s	$\bar{x}$	s
SiO_2	70.91	1.32	72.91	0.86
TiO_2	0.39	0.11	0.29	0.07
Al_2O_3	14.78	0.52	14.30	0.43
Fe_2O_3	0.50	0.45	0.42	0.43
FeO	1.82	0.24	1.31	0.30
MnO	0.06	0.01	0.05	0.01
MgO	1.01	0.15	0.58	0.12
CaO	1.26	0.30	0.81	0.33
Na_2O	3.18	0.45	3.29	0.50
K_2O	5.20	0.27	5.28	0.39
P_2O_5	0.15	0.03	0.12	0.02
Li	271	61	258	59
Rb	249	17	298	21
Be	5	2	6	2
Sr	226	28	175	35
Ba	834	104	643	67
Y	16	1	18	1
La	53	12	39	9
Ce	118	17	92	9
Nd	54	10	46	17
Zr	213	30	152	14
Ni	22	11	19	8
Cu	10	1	9	1
Zn	44	5	42	6
Pb	30	3	31	4

P.I.	1.49	P.I.	1.67
D.I.	85.30	D.I.	89.63

Peralkalinity Index (P.I.) = $Al_2O_3/(Na_2O + K_2O)$
Differentiation Index (D.I.) = Q + or + ab

Table 12. Statistics of major oxide and trace element data from the granite clusters.

	cluster 3 (16)		cluster 4 (2)	
	$\bar{x}$	s	$\bar{x}$	s
SiO_2	74.15	1.09	74.50	1.29
TiO_2	0.19	0.06	0.16	0.02
Al_2O_3	14.19	0.55	14.20	0.10
Fe_2O_3	0.57	0.57	0.44	0.09
FeO	0.81	0.18	0.41	0.34
MnO	0.05	0.01	0.05	0.01
MgO	0.37	0.17	0.14	0.11
CaO	0.51	0.24	0.54	0.16
Na_2O	3.28	0.21	4.84	0.07
K_2O	5.10	0.32	4.69	0.72
P_2O_5	0.10	0.03	0.13	0.02
Li	260	67	347	56
Rb	308	17	479	33
Be	6	2	16	2
Sr	117	23	38	12
Ba	541	93	50	41
Y	17	2	30	11
La	24	8	17	5
Ce	51	22	9	7
Nd	28	15	5	0
Zr	102	15	24	4
Ni	20	12	9	9
Cu	9	1	9	1
Zn	30	6	26	10
Pb	32	6	23	2
P.I.	1.69		1.49	
D.I.	91.53		95.83	

Table 13. Statistical data of significant trend surfaces of granite geochemical data.

variable	order of polynomial surface	fit	correlation coefficient
SiO_2	2	0.39	0.63
TiO_2	3	0.40	0.63
FeO	5	0.64	0.80
MgO	2	0.39	0.63
CaO	2	0.18	0.43
Li	6	0.56	0.75
Rb	2	0.36	0.60
Sr	3	0.59	0.77
Ba	2	0.38	0.62
La	2	0.32	0.57
Ce	5	0.74	0.86
Nd	4	0.59	0.77
Zr	4	0.69	0.83
Zn	3	0.30	0.55
Q	2	0.19	0.44
An	6	0.57	0.75
Bi	5	0.64	0.80
Ap	2	0.17	0.42
Sp	2	0.24	0.49
D.I.	6	0.67	0.83

Table 14. Statistics of primary and secondary dispersion of Cu, Pb, Zn and Ni in the granite.

Primary dispersion

	$\bar{x}$	s
Cu	9	1
Ni	20	9
Pb	31	4
Zn	39	8

Secondary dispersion

	$\bar{x}$	s	$\bar{x}$ + 2s (threshold values)
Cu	12	9	30
Ni	28	23	72
Pb	191	271	733
Zn	214	461	1135

Threshold values are defined as the mean ($\bar{x}$) plus twice the standard deviation (2s) (Hawkes and Webb, 1962) i.e. 1 in 40 samples are defined as anomalous from a normally distributed population.

Table 15A Statistics of the geochemical data of the sphalerite clusters.

	cluster 1 $\bar{x}$	s	cluster 2 $\bar{x}$	s
Zn	63.35	3.05	55.99	3.50
Fe	2.20	0.96	7.35	1.43
Cd	0.35	0.08	0.41	0.29
Mn	26	16	151	95
Ni	4	3	14	15
Co	50	38	90	34
Ag	62	51	560	485

Table 15B. Matrix of product moment correlation coefficients of sphalerite geochemical data.

	Zn	Fe	Cd	Mn	Ni	Co	Ag
Zn	1.00						
Fe	<u>-0.93</u>	1.00					
Cd	0.06	-0.14	1.00				
Mn	<u>-0.87</u>	<u>0.83</u>	-0.22	1.00			
Ni	-0.18	<u>0.87</u>	-0.35	0.10	1.00		
Co	-0.43	<u>0.53</u>	-0.14	0.34	0.40	1.00	
Ag	-0.48	<u>0.51</u>	0.20	<u>0.54</u>	0.19	-0.08	1.00

Significance (α) of values of correlation coefficient (r) with twelve samples:

r	α
0.71	99.5%
0.66	99.0%
0.58	97.5%
0.50	95.0%

Correlations above 95.0% significance are underlined in the matrix above.

Table 16. Means of minor and trace element contents and ratios in minerals from each mineralogical zone.

Sphalerite (ppm):

	COPPER	ZINC(T)	ZINC(P)	ZINC(W)	LEAD
Ag	22	395	347	475	17
Co	64	55	21	111	99
Cd	4300	3400	3800	1700	5500
Mn	6	106	62	178	28
Fe	9800	50900	32500	81600	34800
Zn/Cd	153	249	201	328	128
Zn/Fe	67	18	25	7	26

(T) = total, (P) = Pibble area, (W) = Wood of Cree area.

Galena (ppm):

	COPPER	ZINC	LEAD
Ag	48	281	18
Zn/Cd	-	342	-
Zn/Fe	-	15	-

Chalcopyrite (ppm):

	COPPER	ZINC	LEAD
Ag	188	167	127
Ni	37	217	817
Co	8	63	152
Zn/Cd	96	135	68

For ranges see Figure 101 and Appendix 8.

Table 17. Chemical variation as a result of wallrock alteration at the Orchars vein.

	1	2	3	Δ
SiO_2	74.11	74.50	82.80	1.12
TiO_2	0.23	0.25	0.19	0.83
Al_2O_3	14.26	12.77	9.11	0.64
Fe_2O_3(t)	2.15	0.40	0.48	0.22
MnO	0.05	0.01	0.02	0.40
MgO	0.67	0.40	0.29	0.43
CaO	0.77	0.21	0.19	0.25
Na_2O	3.02	2.54	0.15	0.05
K_2O	5.40	5.57	4.79	0.89
P_2O_5	0.13	0.03	0.01	0.08
H_2O(t)	0.76	1.28	1.24	
Li	227	65	158	0.70
Rb	295	315	325	1.10
Be	4	2	4	1.00
Sr	178	58	-	<0.05
Y	20	76	178	8.90
Zr	152	132	98	0.64
Ni	22	14	<14	0.5
Cu	9	14	13	1.44
Zn	42	8	15	0.36
Pb	31	24	19	0.61

1. Unaltered granite (x), $\bar{x}$ of 57-73, 58-72, 58-74.
2. Wallrock, 2m from contact of vein, 73/W.507B.
3. Wallrock (x_1) adjacent to contact of vein, 73/W.507A.

$\Delta = x_1/x$ (above), a measure of enrichment or depletion, see text.

Table 18. Chemical variation as a result of wallrock alteration at the upper Culcronchie vein.

	1	2	Δ
SiO_2	65.96	87.70	1.33
TiO_2	0.64	0.05	0.08
Al_2O_3	14.65	5.42	0.37
$Fe_2O_3(t)$	6.75	1.37	0.20
MnO	0.21	0.02	0.10
MgO	4.19	0.45	0.11
CaO	0.91	0.09	0.10
Na_2O	1.55	0.09	0.06
K_2O	3.27	1.72	0.56
P_2O_5	0.09	0.00	<0.10
$H_2O(t)$	1.93	0.78	
Li	156	50	0.32
Rb	136	50	0.37
Be	1	2	
Sr	97	11	0.11
Y	22	-	<0.05
Zr	166	53	0.32
Ni	99	60	0.61
Cu	33	145	contaminated
Zn	86	137	by sulphides
Pb	34	543	
Cr	161	100	0.62

1. Unaltered black pelitic hornfels (74/H. 48-66) (x).
2. Black pelitic hornfels wallrock (72/W. 085) (x_1)

$\Delta = x_1/x$ (table 17).

Table 19. Chemical variation as a result of wallrock alteration at the Wood of Cree vein.

	1	2	Δ
SiO_2	67.89	78.90	1.16
TiO_2	0.65	0.50	0.77
Al_2O_3	11.60	5.77	0.50
$Fe_2O_3(t)$	5.18	1.01	1.19
MnO	0.08	0.05	0.63
MgO	3.66	2.29	0.63
CaO	2.46	3.09	1.26
Na_2O	2.39	0.06	0.03
K_2O	2.09	3.06	1.46
P_2O_5	0.16	0.12	0.75
$H_2O(t)$		1.04	
Li	92	190	2.07
Rb	75	131	1.75
Be	2	2	1.00
Sr	279	15	0.05
Y	15	8	0.53
Zr	272	205	0.75
Ni	73	100	1.37
Cu	26	27	1.04
Zn	61	1525	contaminated
Pb	24	156	by sulphides
Cr	181	176	0.97

1. Average Silurian greywacke from the Fleet area (table 1) (x).
2. Wallrock adjacent to vein (73/W.518A) (x_1).

$\Delta = x_1/x$ (table 17).

Table 20. Chemical variation as a result of wallrock alteration at the Bargaly (N.-S.) vein.

	1	2	3	Δ
SiO_2	70.48	79.10	76.90	1.09
TiO_2	0.72	0.63	0.54	0.75
Al_2O_3	11.43	9.52	11.18	0.98
Fe_2O_3(t)	5.02	0.67	0.32	0.06
MnO	0.09	0.01	0.01	0.11
MgO	3.63	0.21	0.27	0.07
CaO	1.31	0.27	0.26	0.20
Na_2O	2.47	0.09	0.05	0.02
K_2O	1.43	7.42	8.04	5.62
P_2O_5	0.20	0.03	0.06	0.30
H_2O(t)	2.07	0.91	0.68	
Li	90	90	100	1.11
Rb	52	117	223	4.29
Be	2	2	2	1.00
Sr	283	77	57	0.21
Y	16	-	26	0.60
Zr	296	141	239	0.81
Ni	89	34	20	0.22
Cu	26	31	37	1.42
Zn	55	1313	1390	contaminated
Pb	24	6475	1699	by sulphides
Cr	236	346	176	0.75

1. Greywacke hornfels 500 m from vein contact (74/H. 46-68) (x).

2. Wallrock adjacent to western margin of N.-S. vein (72/W. 428).

3. Wallrock breccia fragment from within the N.-S. vein (72/W. 428A) (x_1).

$\Delta = x_1 / x$ (table 17).

Table 21. Chemical variation as a result of wallrock alteration at the Dallash vein.

	1	2	Δ
SiO_2	65.59	76.40	1.10
TiO_2	0.78	0.62	0.79
Al_2O_3	11.74	9.72	0.82
$Fe_2O_3(t)$	5.14	2.94	0.57
MnO	0.07	0.05	0.71
MgO	3.85	2.41	0.63
CaO	2.24	1.47	0.66
Na_2O	2.67	0.33	0.12
K_2O	2.41	4.24	1.76
P_2O_5	0.20	0.07	0.35
$H_2O(t)$	0.84	2.00	
Li	96	118	1.23
Rb	82	139	1.70
Be	-	6	> 6
Sr	305	27	0.09
Y	18	8	0.44
Zr	272	205	0.75
Ni	68	100	1.47
Cu	24	32	1.33
Zn	61	49	1.69
Pb	29	762	contaminated by sulphides
Cr	178	289	1.62

1. Greywacke hornfels 500 m from vein contact (74/H.47-69) (x).

2. Greywacke wallrock adjacent to footwall contact (74/W. 519A) (x_1).

$\Delta = x_1/x$ (table 17).

Table 22. Analyses of standard rocks from this laboratory compared with recommended analyses.

T - 1	1	2			3
SiO_2	62.7	62.4	-	63.0	62.71
TiO_2	0.61	0.51	-	0.61	0.56
Al_2O_3	15.73	16.21	-	16.73	16.47
Fe_2O_3	3.06	2.55	-	3.01	2.78
FeO	2.65	2.73	-	3.03	2.88
MnO	0.11	0.08	-	0.12	0.10
MgO	2.19	1.76	-	2.01	1.90
CaO	4.97	4.98	-	5.40	5.19
Na_2O	4.45	4.17	-	4.47	4.32
K_2O	1.26	1.19	-	1.31	1.25
P_2O_5	0.11	0.12	-	0.16	0.14
H_2O^+	1.08	1.36	-	1.72	1.54
H_2O^-	0.06				
GSP-1	1	4			5
Li	29	25	-	47	32
Be	2	0.5	-	3	1.5
Cu	38	15	-	54	33
Pb	40	14	-	80	51
Zn	110	54	-	340	98
Ni	20	3	-	25	12
Cr	19	5	-	18	12
G-2	6				
Rb	173	120	-	513	168
Sr	462	235	-	680	479
Y	9	8	-	17	12
Zr	318	270	-	400	300
Cu	10	6	-	17	12
Pb	29	15	-	43	31
Zn	78	42	-	105	85

1, by rapid wet chemical techniques (appendix 1); 2, range from other laboratories; 3, mean from other laboratories; 4, range from Flanagan (1969); 5, recommended values from Flanagan (1973); 6, by X.R.F. (appendix 1).

Table 23. Statistics of replicate analyses of the internal granite standard 73/G 55-75.

Rapid wet chemical method (appendix 1)

	$\bar{x}$	n	range	s	C(%)
SiO_2	68.5	4	67.8 - 69.6	0.6	0.88
TiO_2	0.50	10	0.48 - 0.54	0.02	4.0
Al_2O_3	15.05	10	14.74 - 15.54	0.23	1.5
FeO	2.54	10	2.36 - 2.85	0.12	4.7
MnO	0.06	10	0.05 - 0.06	0.003	5.0
MgO	1.29	10	1.27 - 1.30	0.025	1.9
CaO	2.02	10	1.94 - 2.09	0.04	2.0
Na_2O	3.39	10	3.33 - 3.45	0.035	1.0
K_2O	4.34	10	4.29 - 4.41	0.037	0.8
Li	297	5	294 - 302	3	1.0
Be	5	5	4 - 6	1	15.4
Cu	17	4	13 - 20	3	15.0
Pb	65	5	59 - 69	3	5.1
Zn	71	5	69 - 73	1	2.0
Ni	33	5	25 - 42	6	17.1
Cr	40	5	35 - 44	3	7.1
X ray fluorescence					
Rb	222	10	215 - 225	4	1.8
Sr	226	10	263 - 270	3	1.3
Y	23	10	22 - 24	1	4.0
Zr	262	10	260 - 264	1	0.4
Cu	11	10	10 - 11	0.5	4.5
Pb	31	10	26 - 34	3	9.7
Zn	62	10	60 - 63	1	1.6

n = number of analyses

C = coefficient of variation (in per cent) = $\frac{100s}{\bar{x}}$

Table 24. Comparison of sulphide analyses with those recommended for sulphide ore standards and statistics of replicate analyses.

Atomic absorption spectrophotometry (appendix 1).

	Lead ore		Zn ore		Cu ore	
	f	r	f	r	f	r
Pb	78.3	75.6	0.97	0.91	0.47	-
Cu	0.13	0.14	0.11	0.10	18.3	23.6
Zn	3.45	3.40	53.5	51.4	0.89	-
Fe	1.42	1.35	10.2	10.0	25.9	26.9
Mn	0.22	0.21	0.96	1.12	317	-
Co	80	-	219	-	275	-
Ni	20	-	10	-	135	-
Cd	152	-	1800	2200	56	-
Ag	737	740	31	-	-	-

	$\bar{x}$	n	range	s	C
Pb	0.96	5	0.95 - 0.97	0.008	0.83
Cu	1176	5	1061 - 1092	13	1.21
Zn	53.4	5	52.2 - 55.2	1.06	1.99
Fe	10.6	5	10.4 - 10.8	0.14	1.33
Mn	0.95	5	0.95 - 0.97	0	0
Co	224	5	217 - 230	5	2.23
Cd	1980	5	1930 - 2030	43	2.17
Ag	759	5	746 - 785	14	1.84

f. result of analysis from this laboratory.

r. recommended analysis.

FIGURES.

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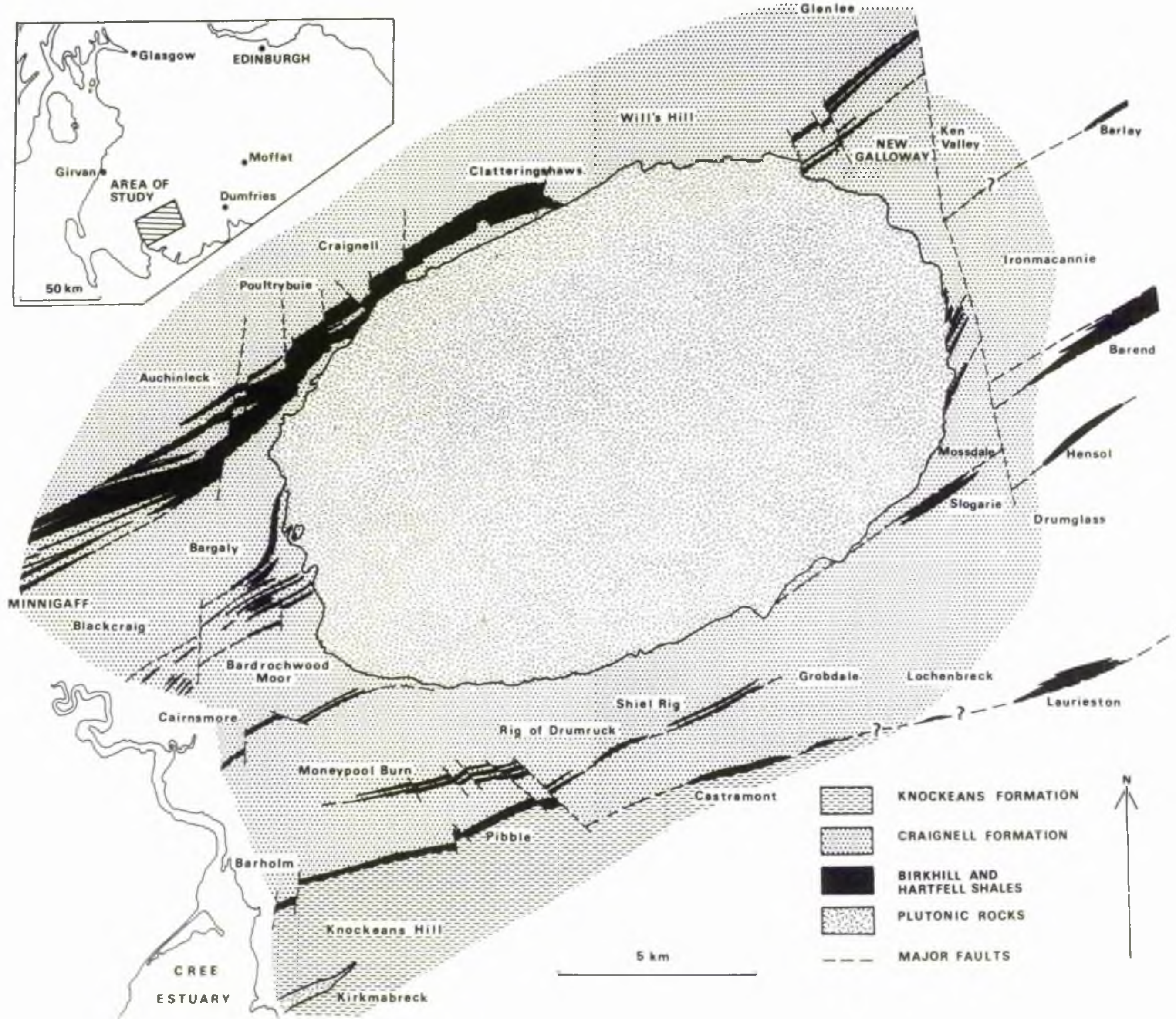
FIGURES 1 - 8.



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Girvan
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Barlay
Clatteringshaws
Craignell
Poultrybuie
Auchinleck
Ironmacannie
Barend
Mossdale
Hensol
Slogarie
Drumglass
Bargaly
MINNIGAFF
Blackcraig
Bardrochwood Moor
Grobdale
Lochenbreck
Laurieston
Cairnsmore
Shiel Rig
Rig of Drumruck
Moneypool Burn
Castramont
Pibble
Barholm
Knockeans Hill
CREE ESTUARY
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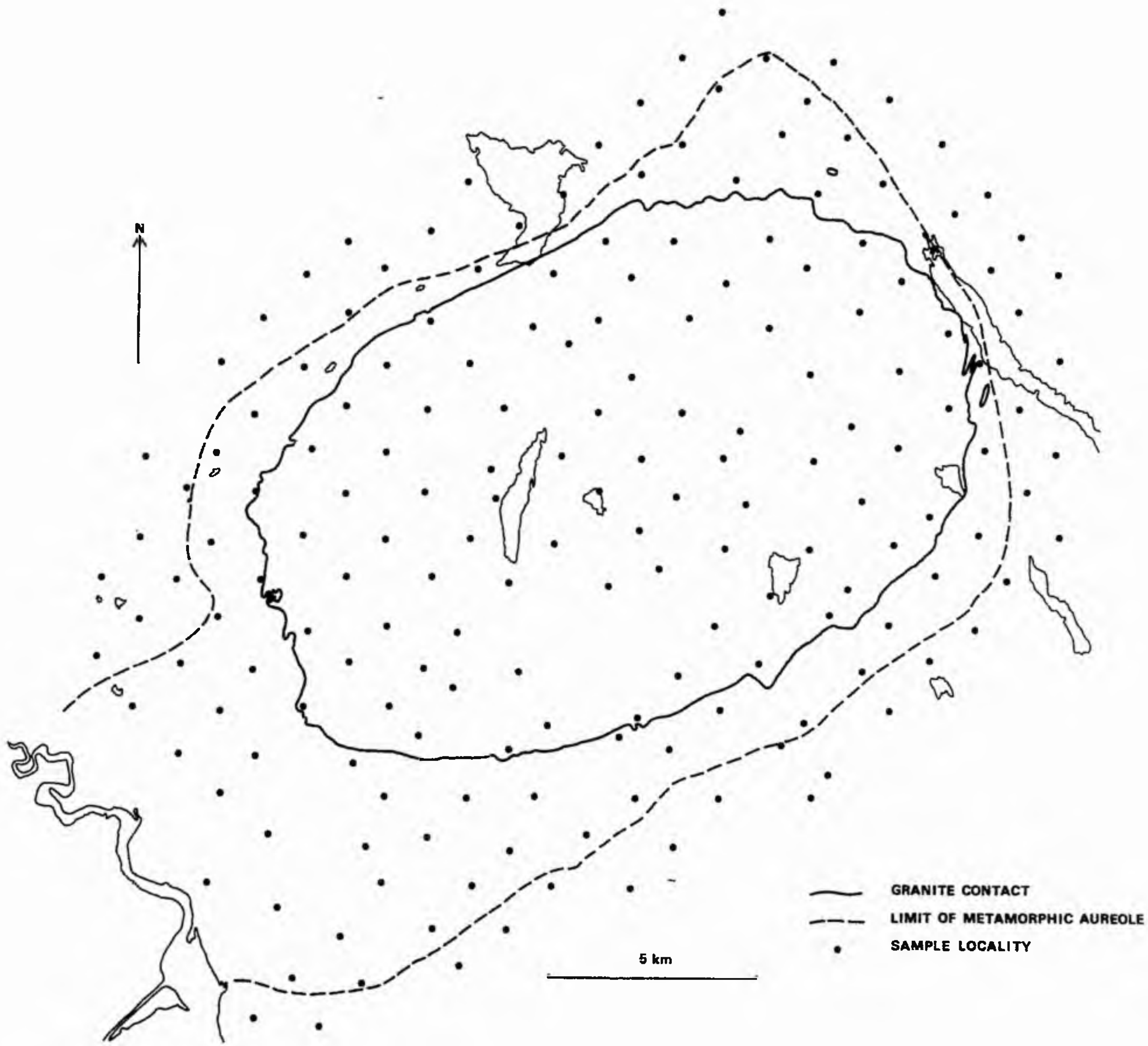
CRAIGNELL FORMATION
BIRKHILL AND HARTFELL SHALES
PLUTONIC ROCKS
MAJOR FAULTS
N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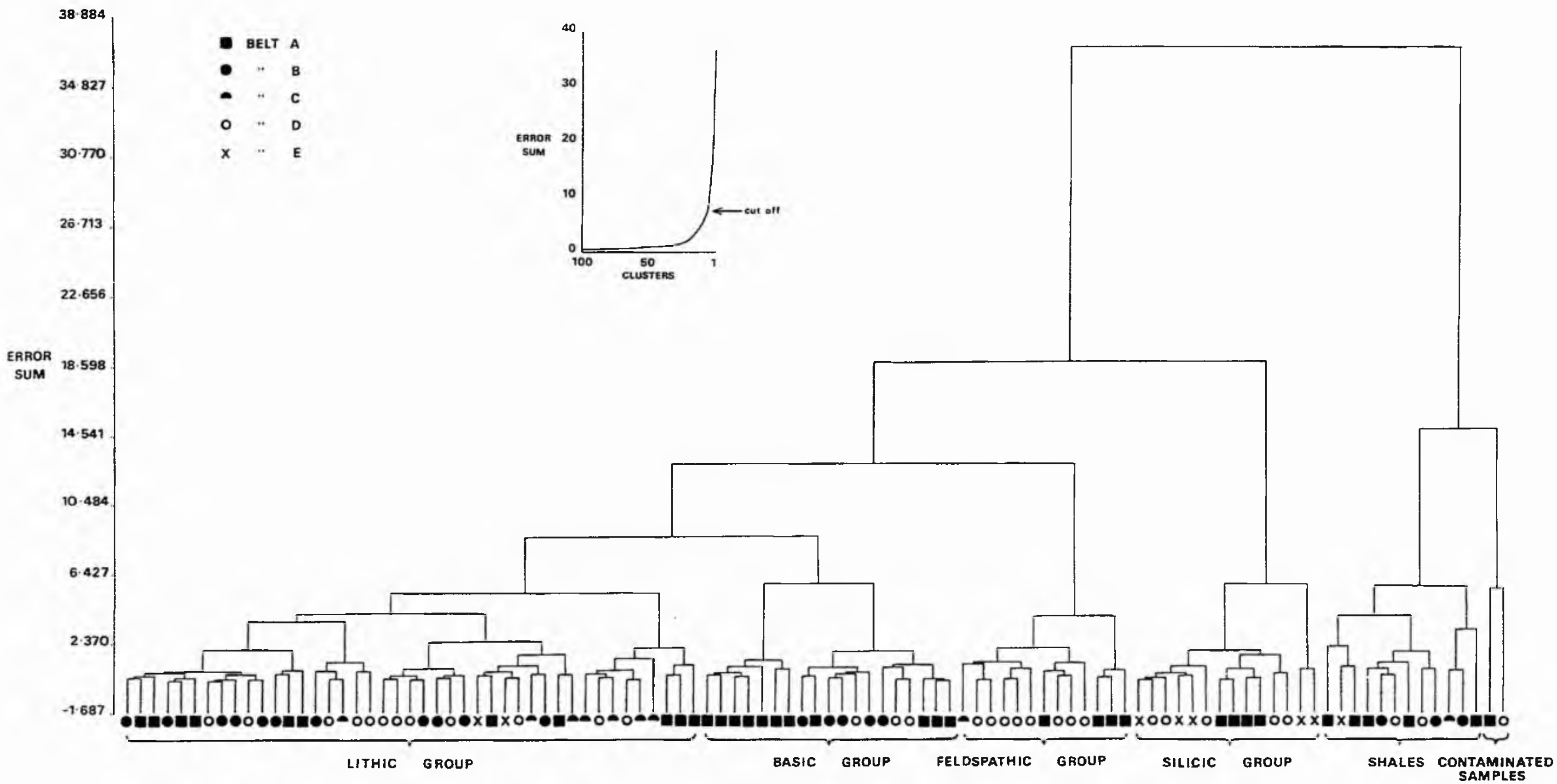
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" B
" C
" D
" E
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30
ERROR SUM
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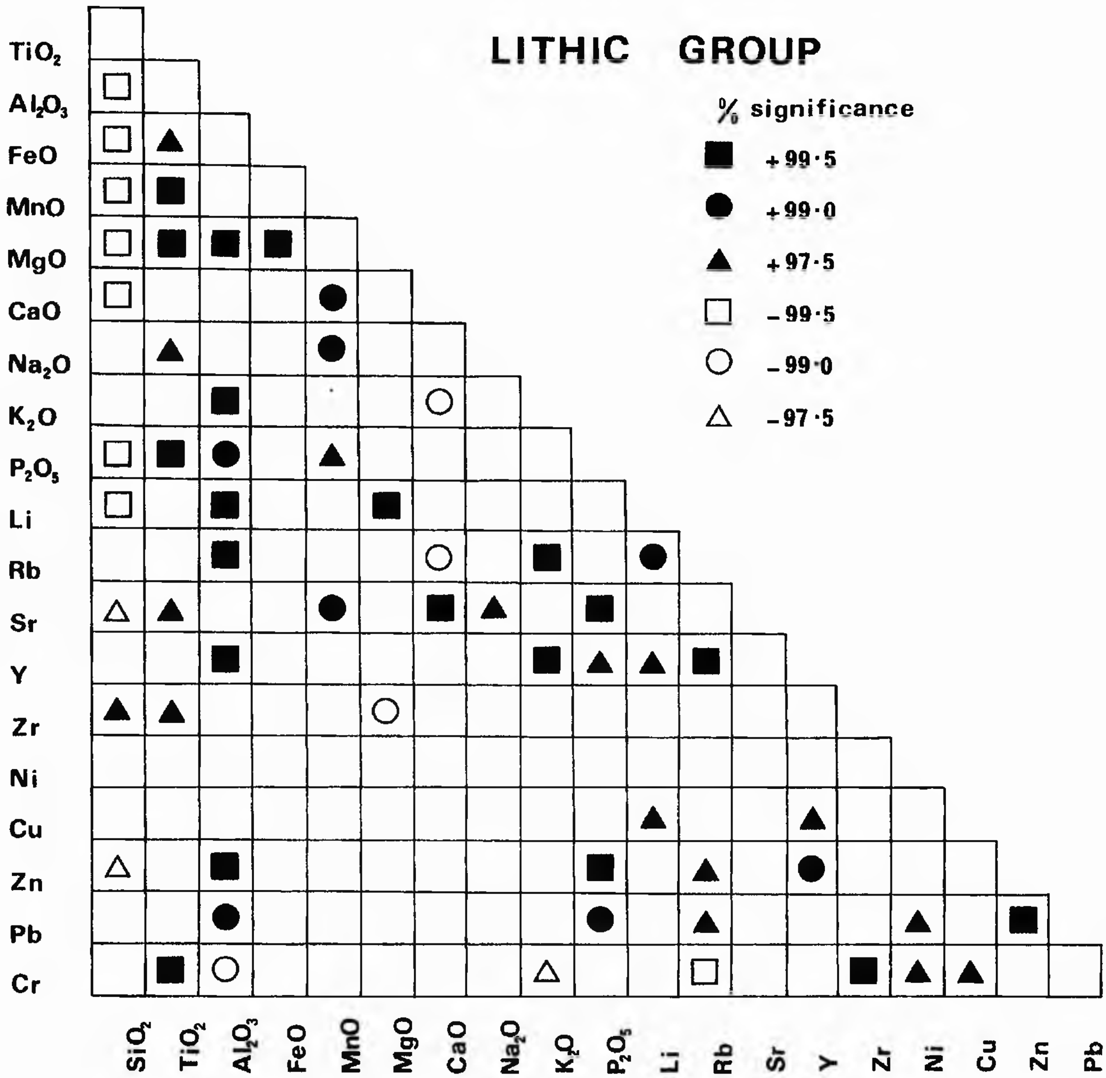
FELDSPATHIC GROUP
SILICIC GROUP
SHALES
CONTAMINATED SAMPLES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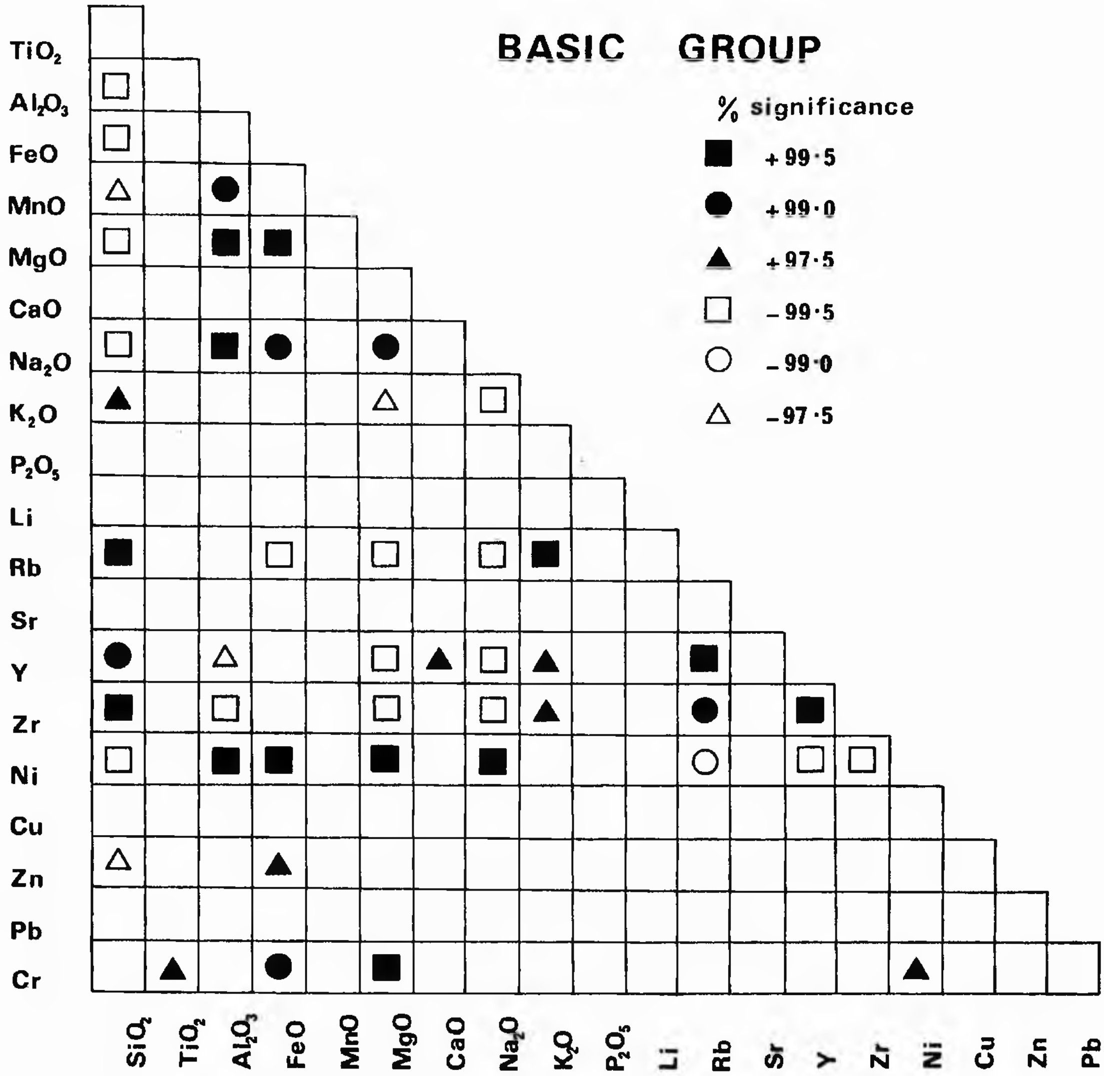
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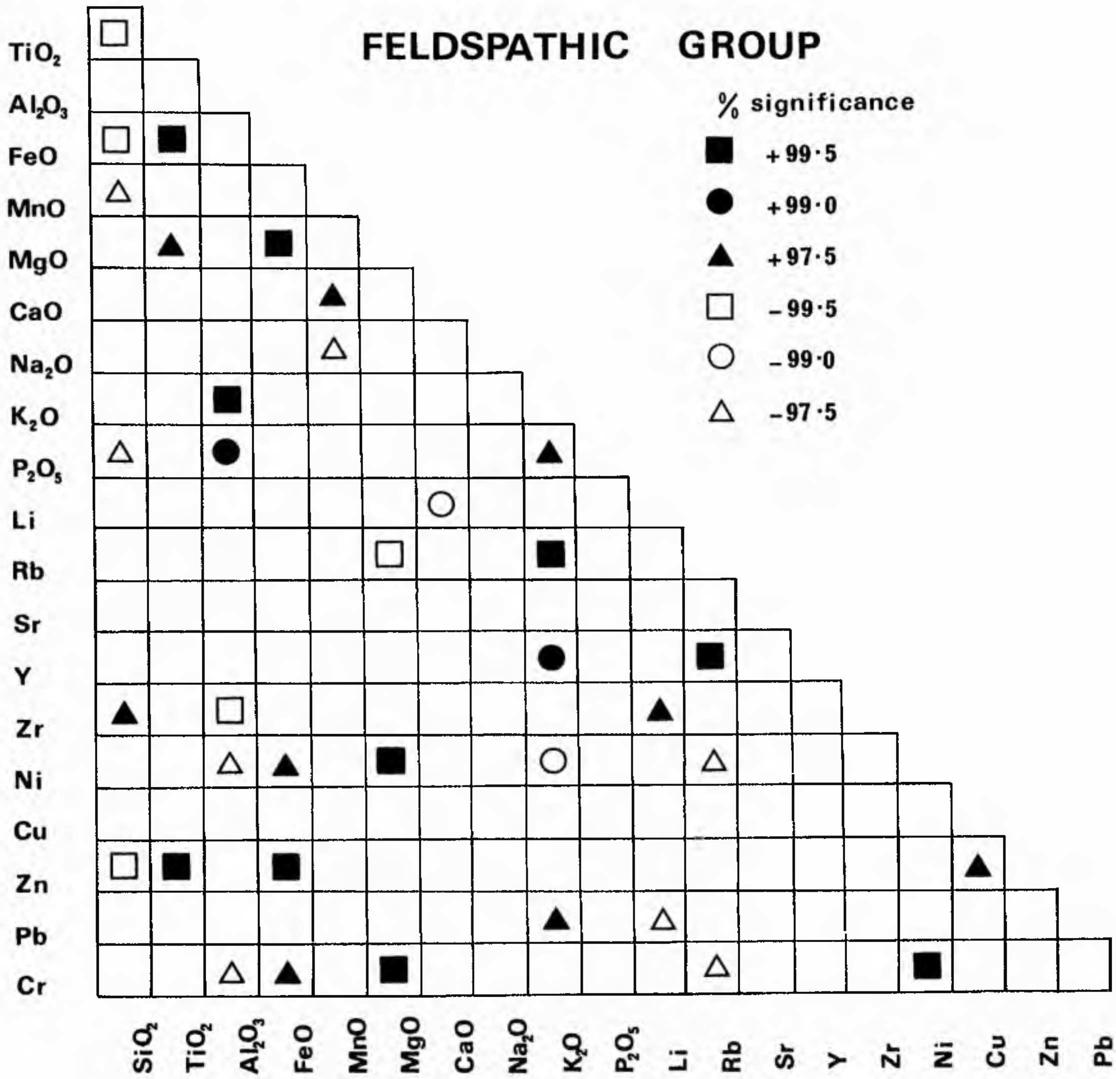
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Al2O3
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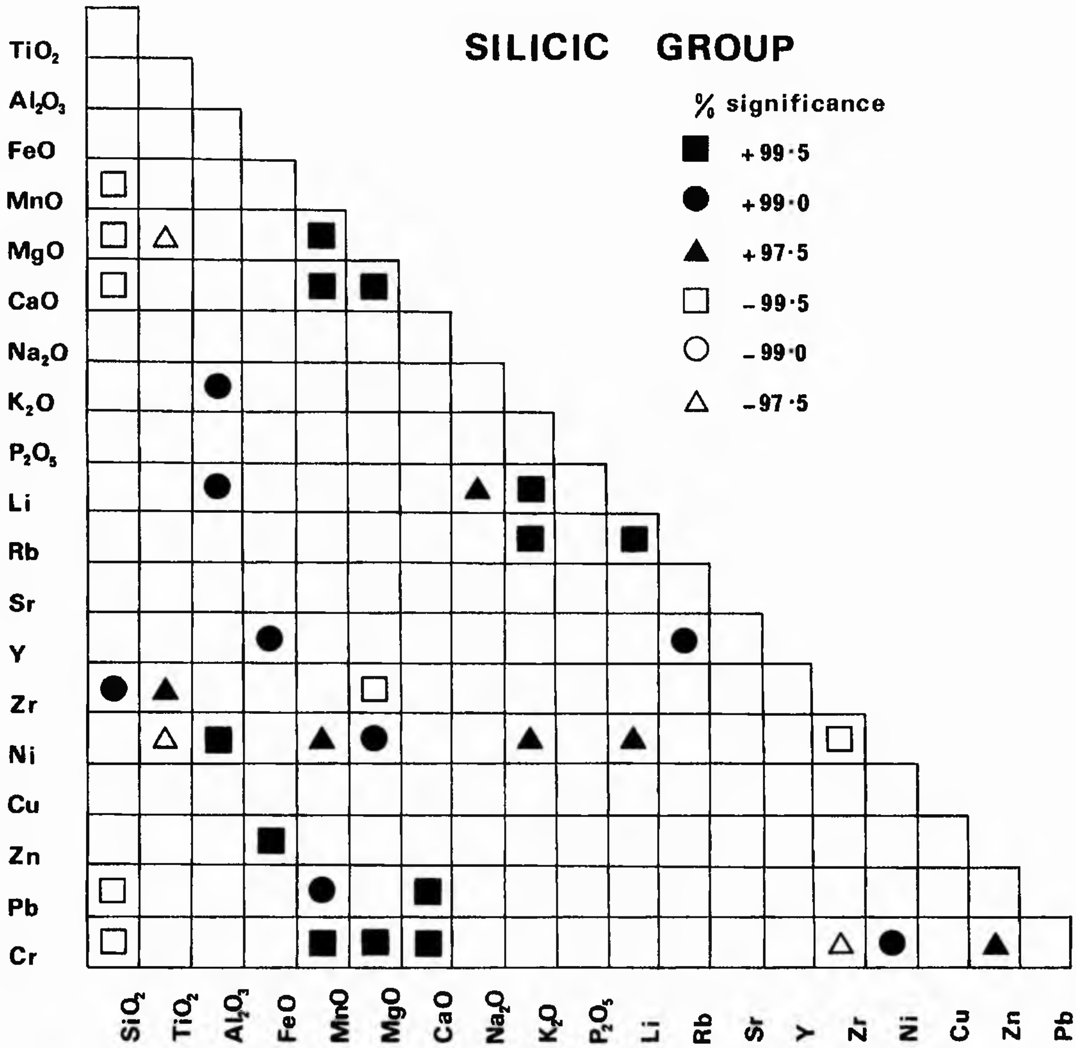
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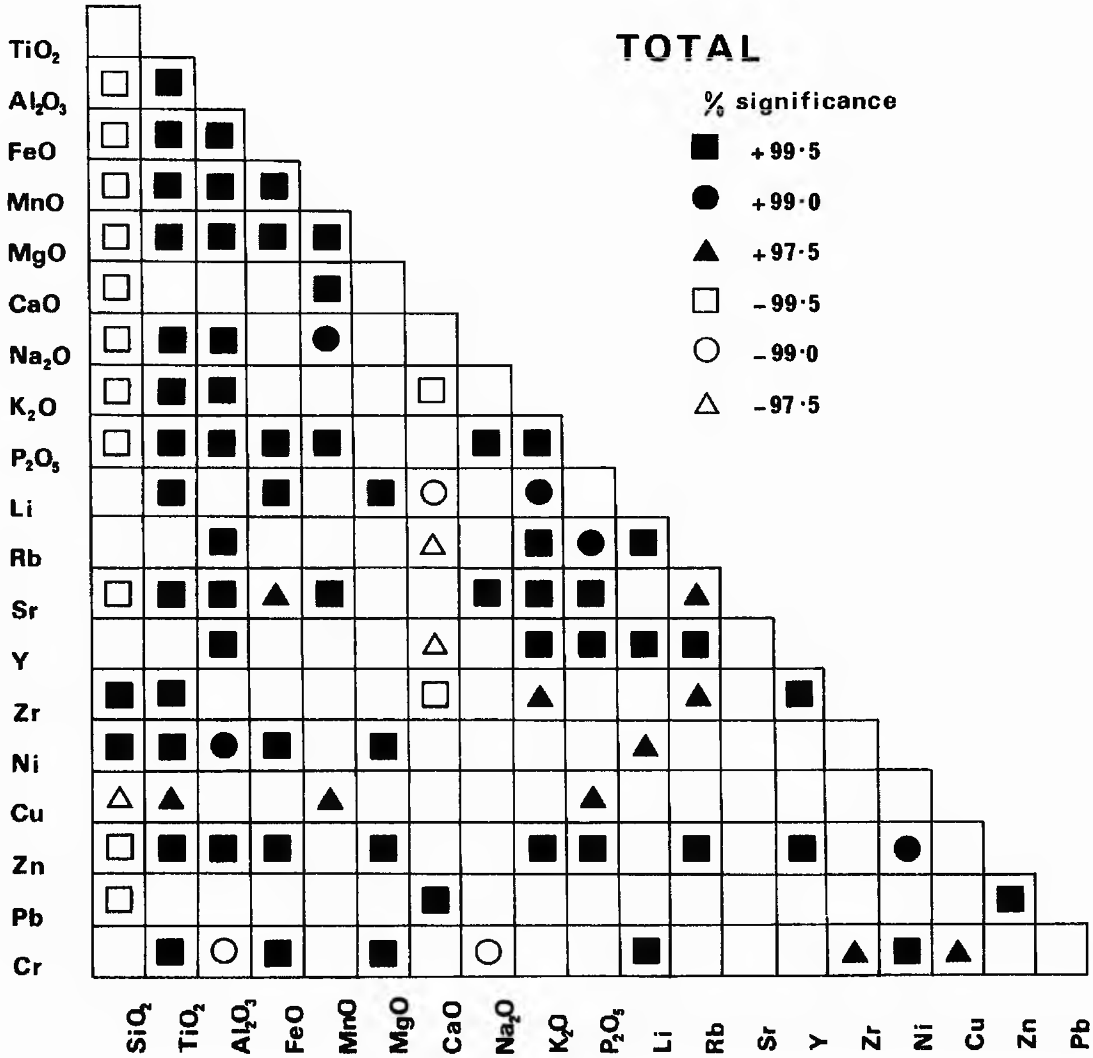
SiO2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K_2O
P_2O_5
Li
Rb
Sr
Y
Zr
Ni
Cu
Zn
Pb
Cr
SiO_2

FIGURES 9 - 14.

FIG. 9. Ternary diagrams of selected trace elements showing their influence on the various greywacke groups.

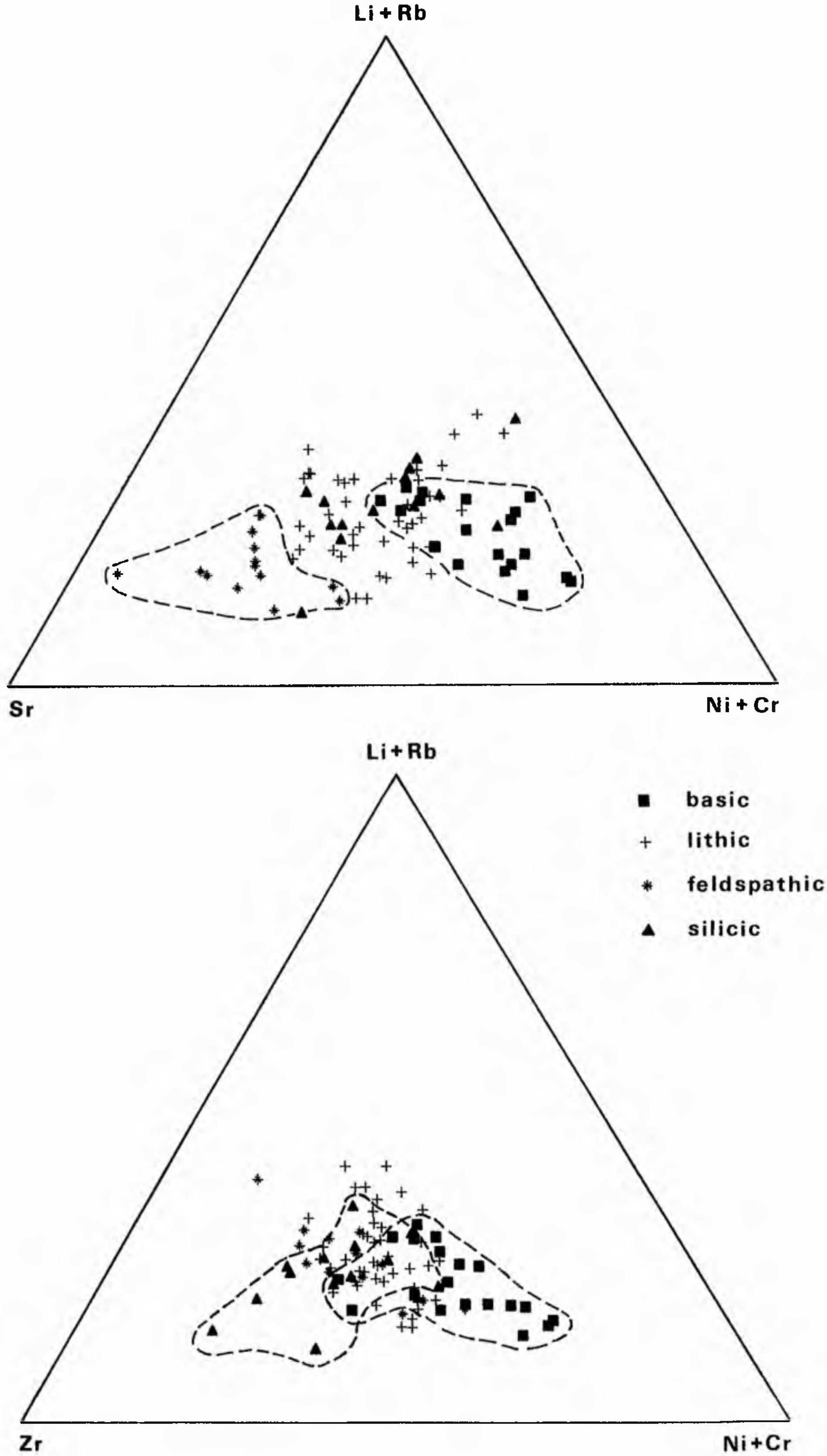
FIG. 10. Scatter diagrams of 'granitic' elements in the greywackes. Regression lines on all scatter diagrams have a significance greater than 95.0% for correlations (r) with a significance greater than 97.5%. Sample points: + = lithic group, * = feldspathic group, ⊡ = basic group, △ = silicic group. Regression lines: l = lithic group, f = feldspathic group, b = basic group, s = silicic group, t = total data set.

FIG. 11. Scatter diagrams of 'granitic', 'resistate' and 'basic' elements in the greywackes (key, see Fig. 10).

FIG. 12. Scatter diagrams of 'basic' elements in the greywackes (key, see Fig. 10).

FIG. 13. Scatter diagrams of chemical variables in the greywackes (key, see Fig. 10).

FIG. 14. Scatter diagrams showing variations in chemistry with SiO_2 content of greywackes (key, see Fig. 10).



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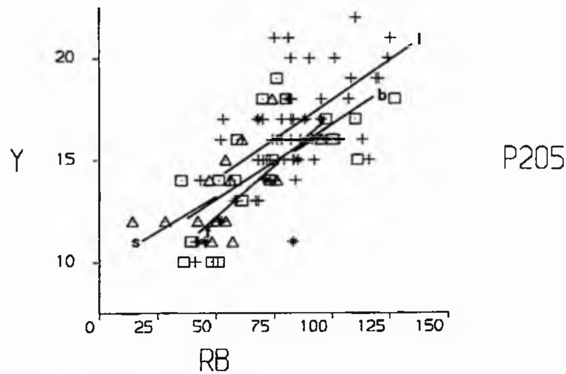
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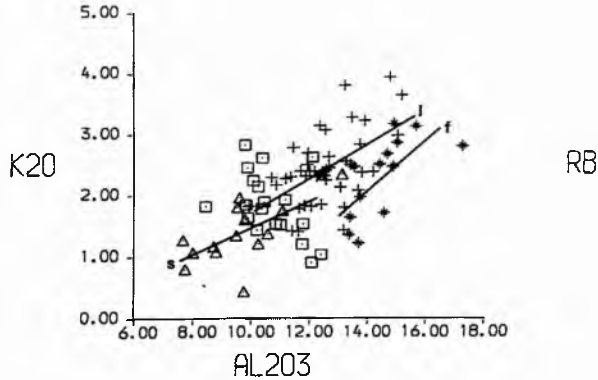
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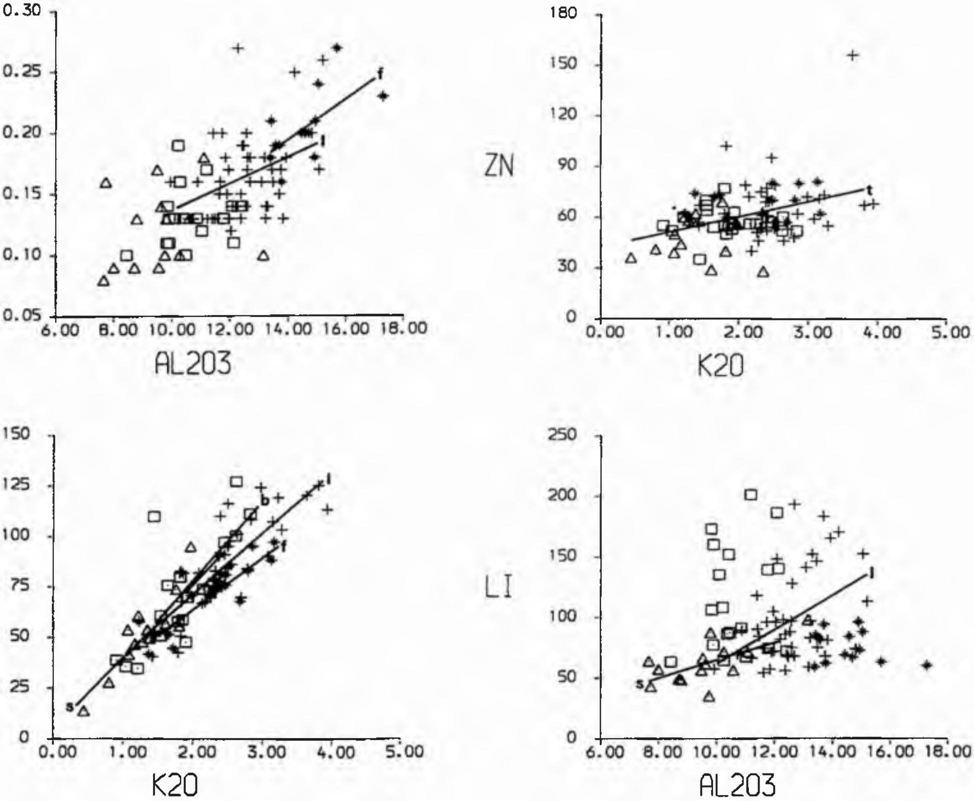

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120
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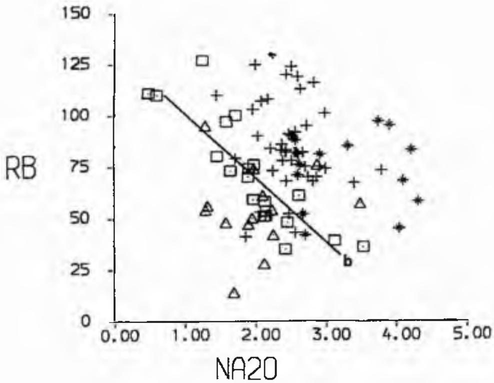

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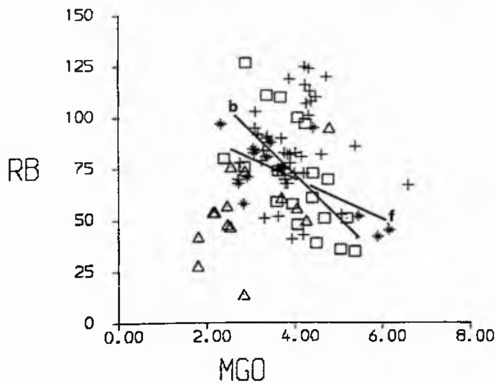
ZR



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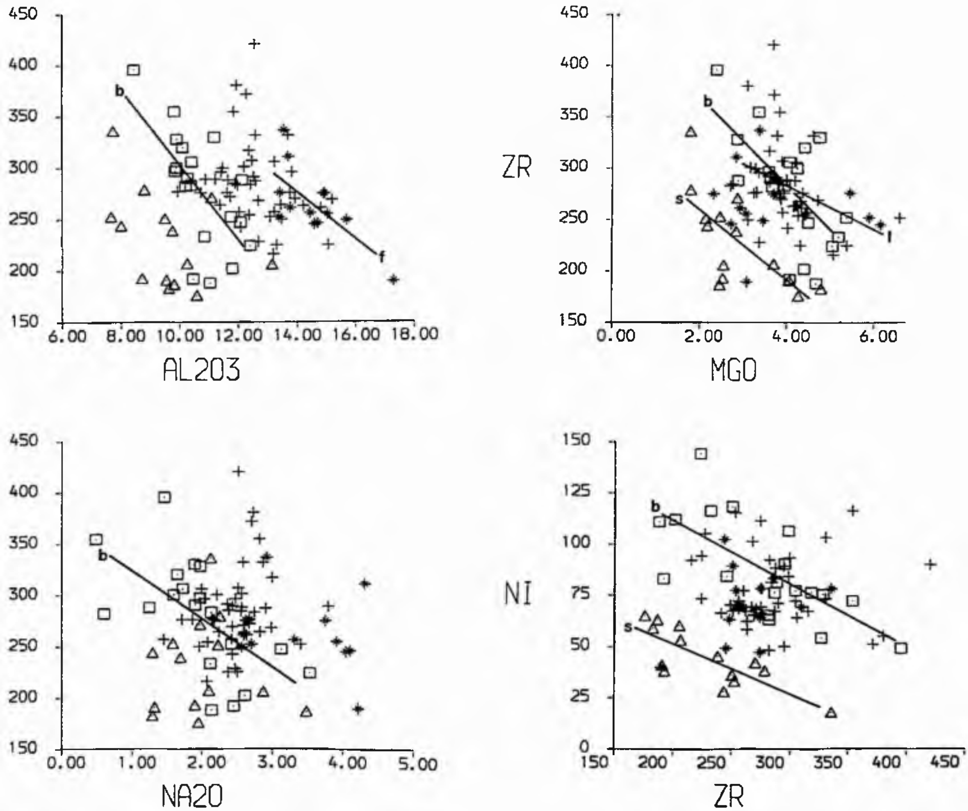
ZR



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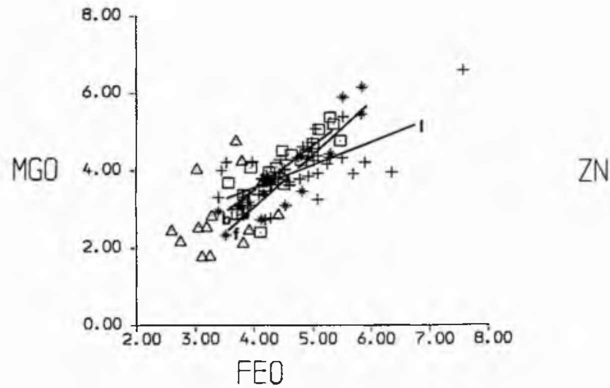
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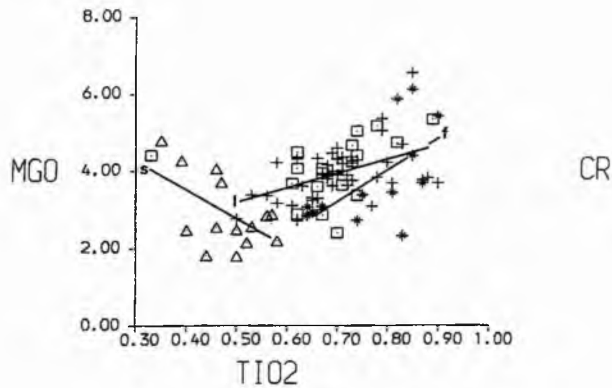
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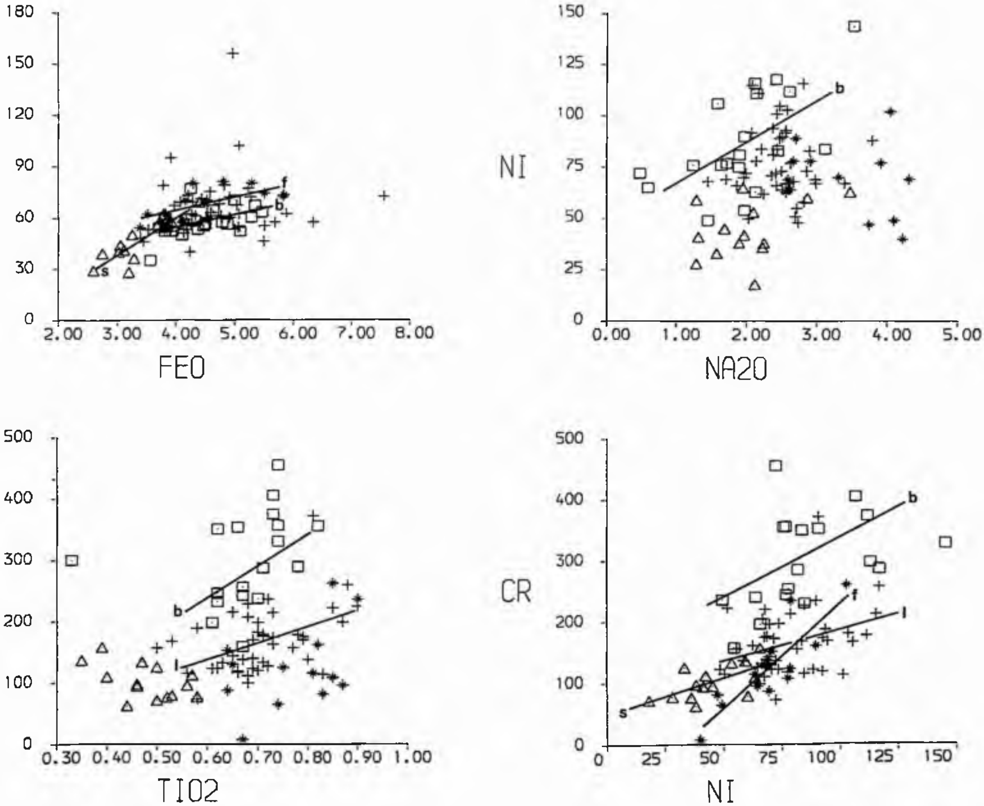
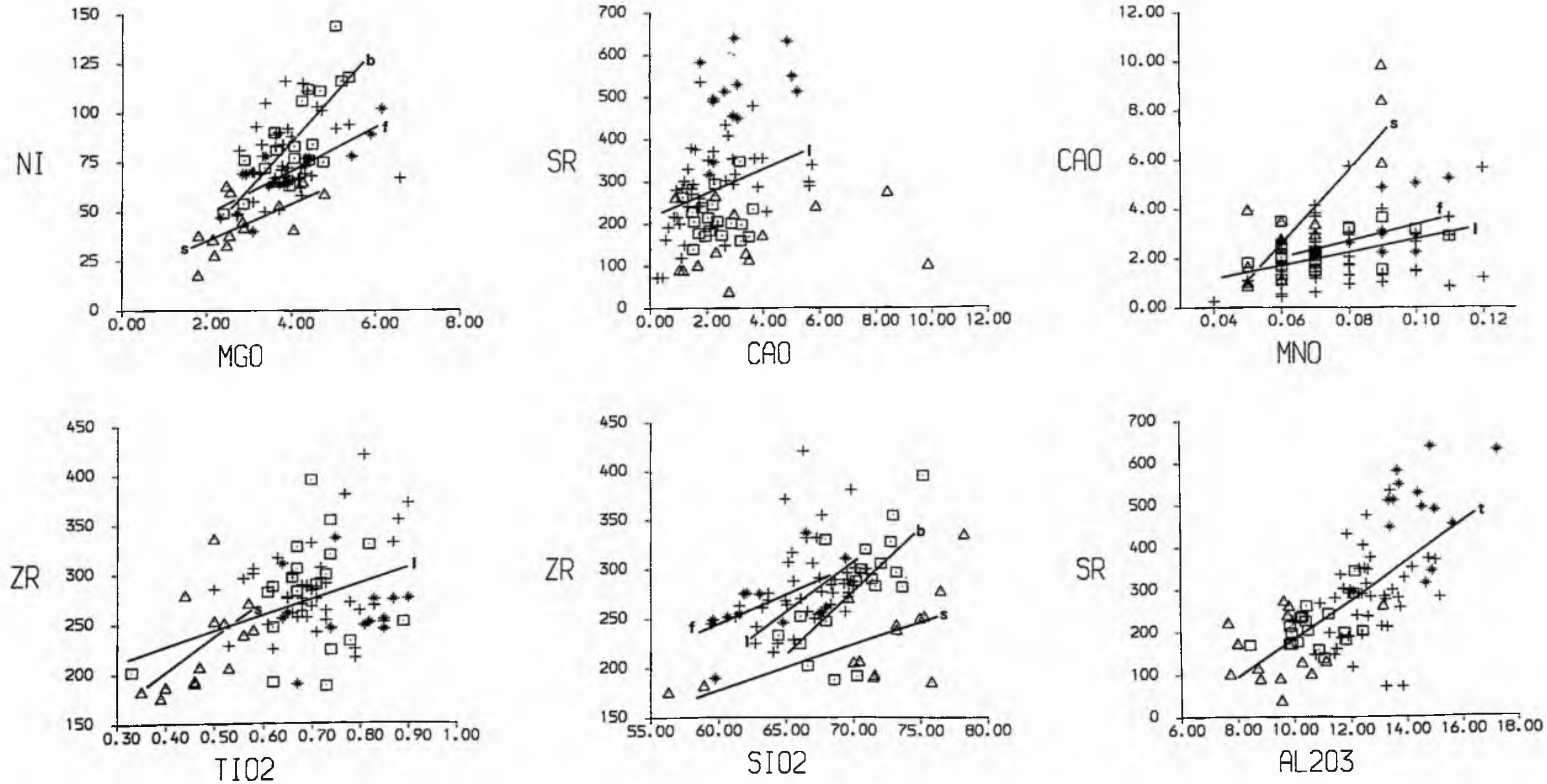
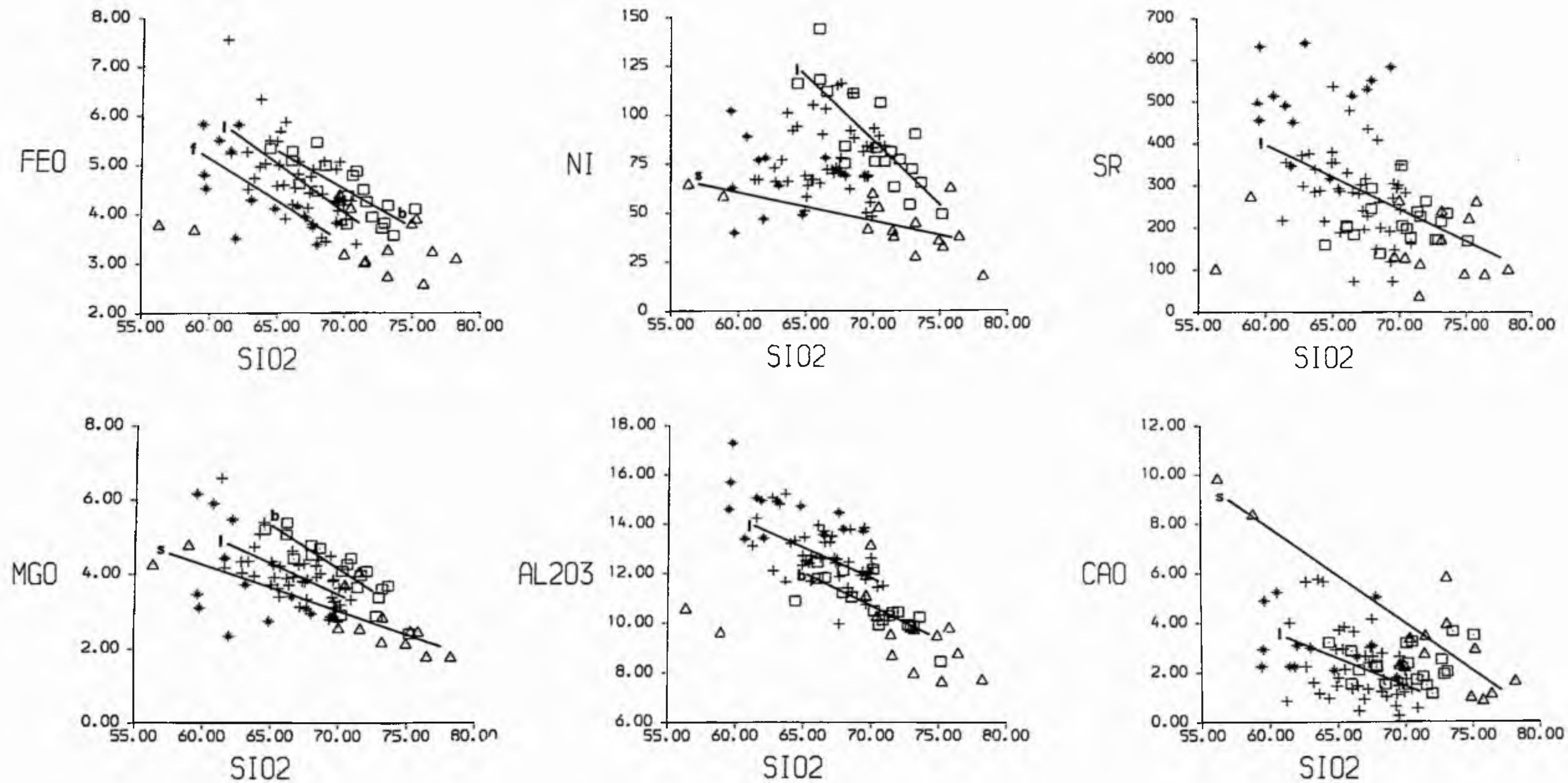
0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
TIO2

12



NI
FEO
NA2O
CR
TIO2
NI


NI
MGO
SR
CAO
CAO
MNO
ZR
TIO2
ZR
SIO2
SR
AL2O3


FEO
SIO2
NI
SIO2
SR
SIO2
MGO
SIO2
AL2O3
SIO2
CAO
SIO2

FIGURES 15 - 19.

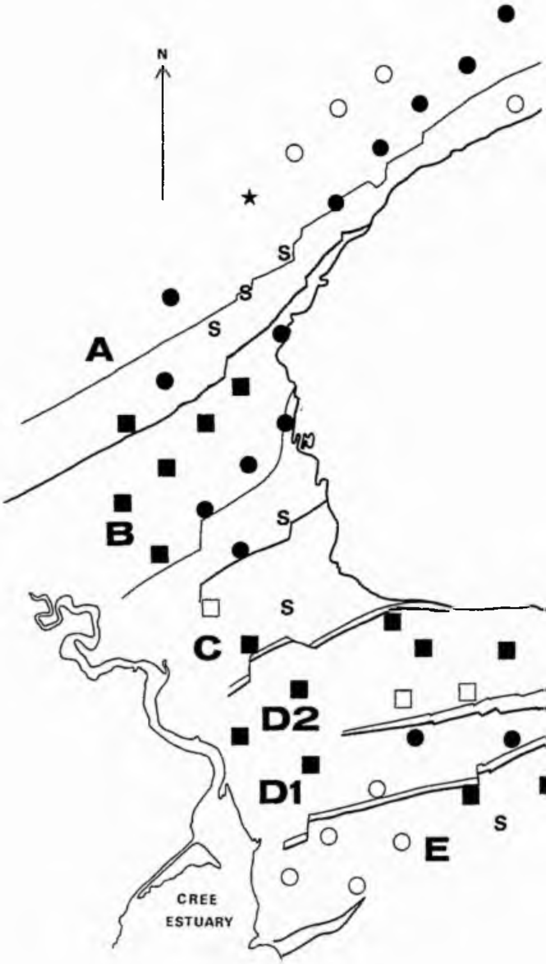
FIG. 15. Distribution of samples within each geochemical cluster. Outline geology as in Figs. 1 and 23. A = Auchinleck-Glenlee Belt, B = Blackcraig-Ironmacannie Belt, C = Cairnsmore-Mossdale Belt, D = Barholm-Drumglass Belt, E = Knockeans-Castramont Belt.

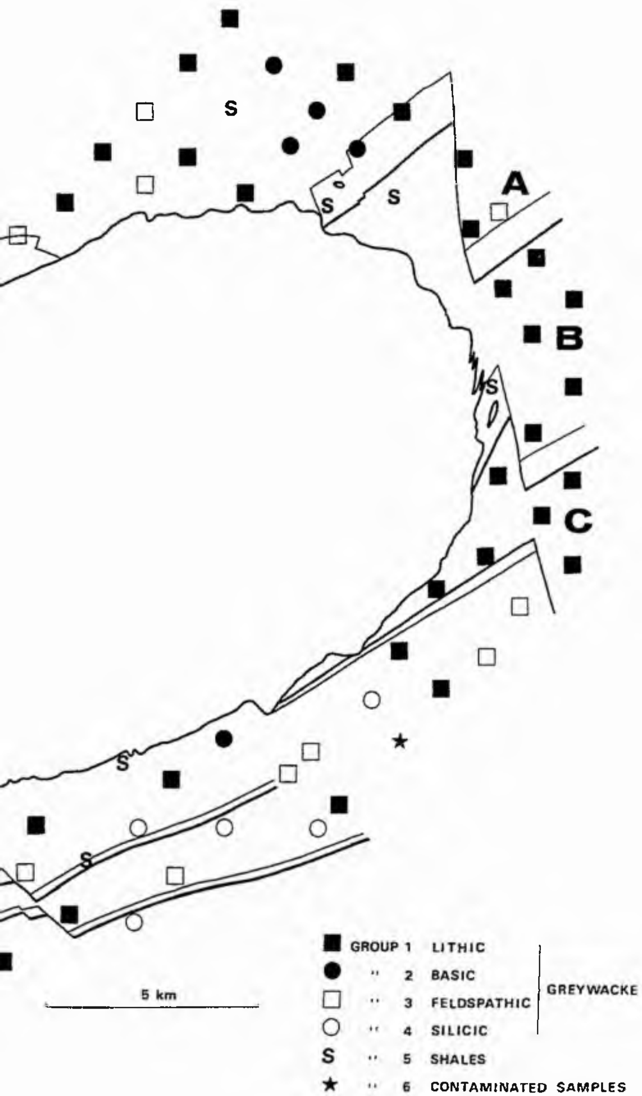
FIG. 16. Pie diagrams indicating the proportions of the geochemical clusters in each structural belt. A - E as in Fig. 15.

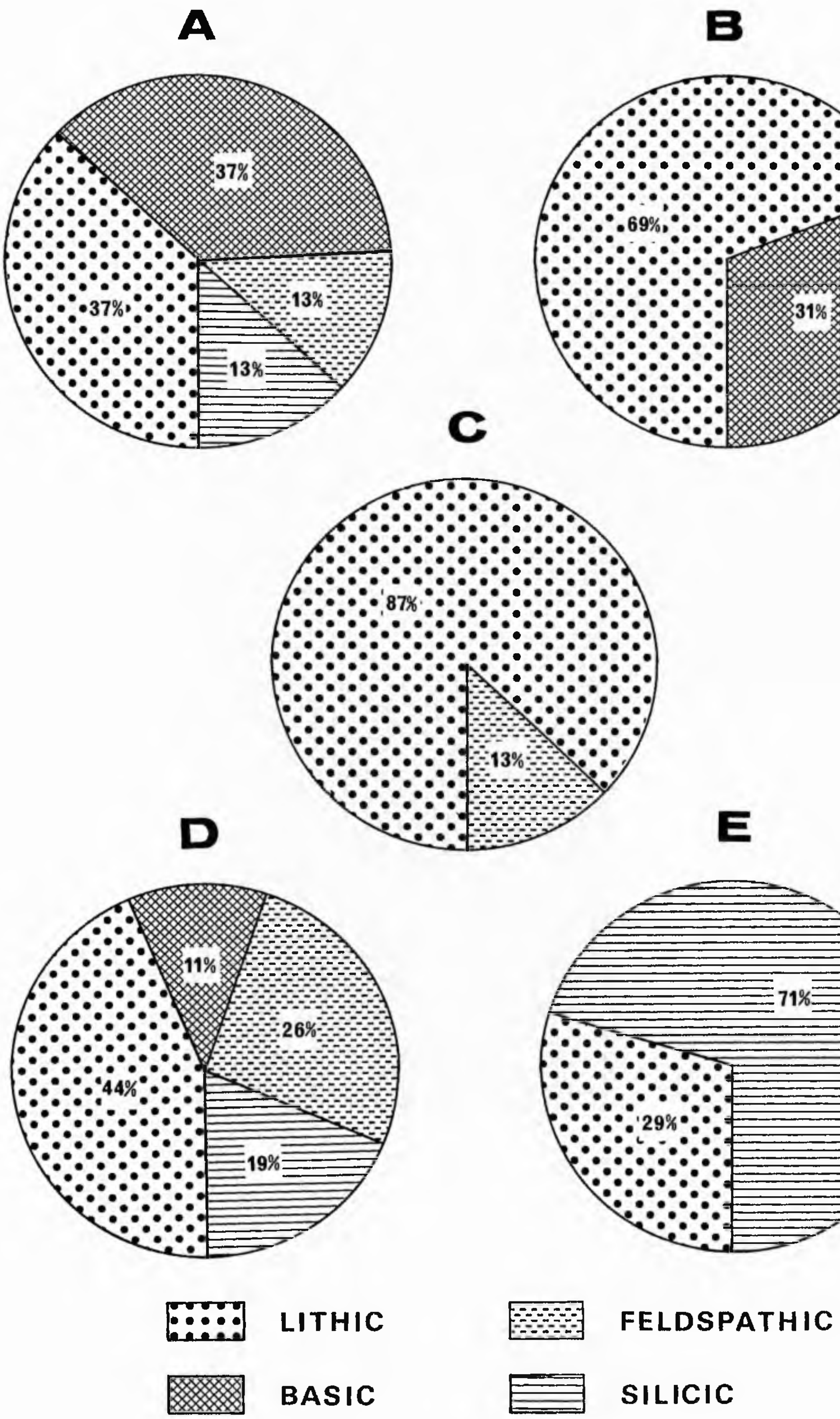
FIG. 17. Block diagram showing the disposition of the various geochemical greywacke types within the Craignell Formation. Arrows indicate the contacts between the basic (B), lithic (L) and silicic (S) facies.

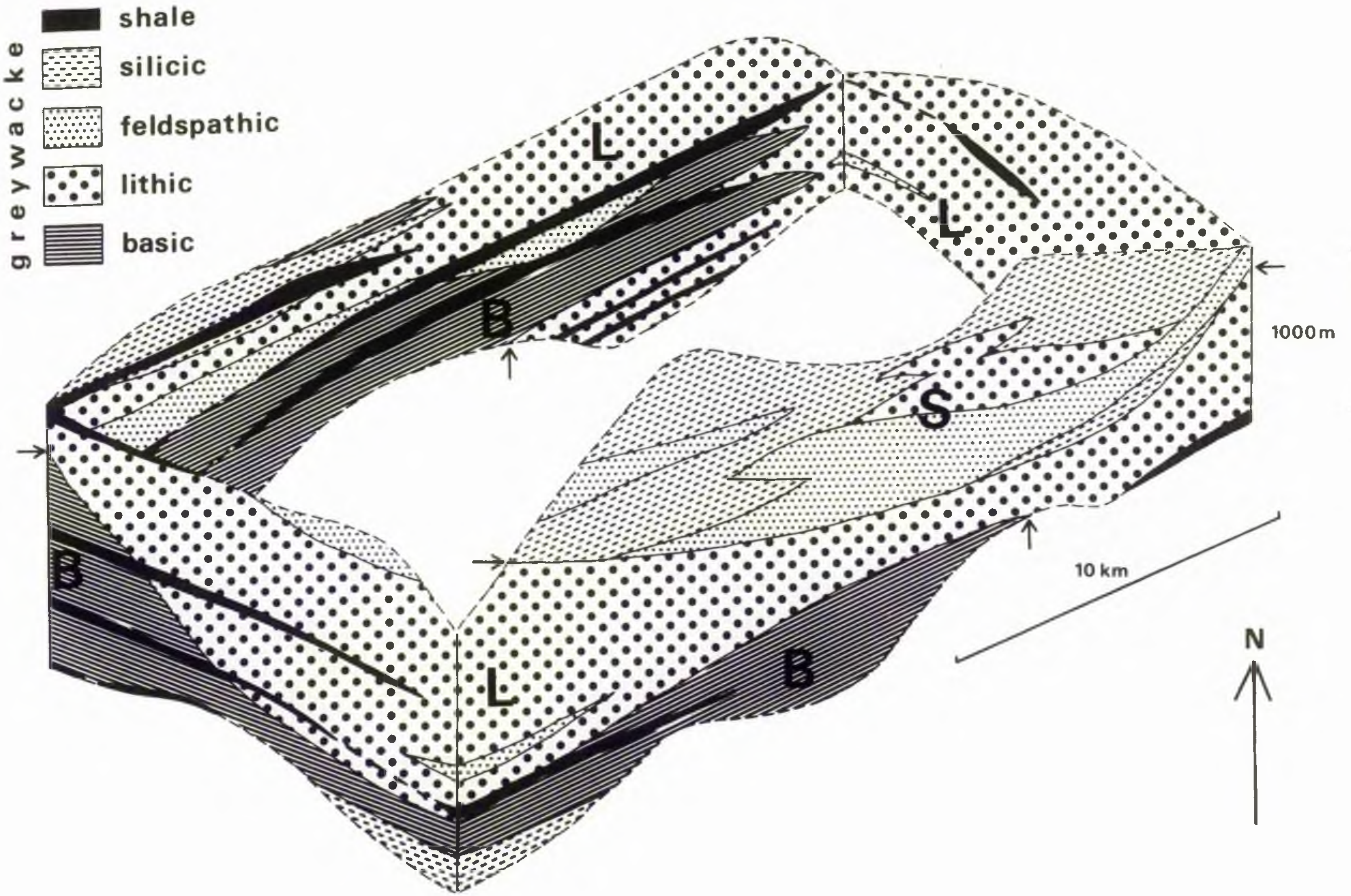
FIG. 18. Correlation diagram of the Craignell Formation between Auchinleck (west) and the Ken valley (east) (see Fig. 1).

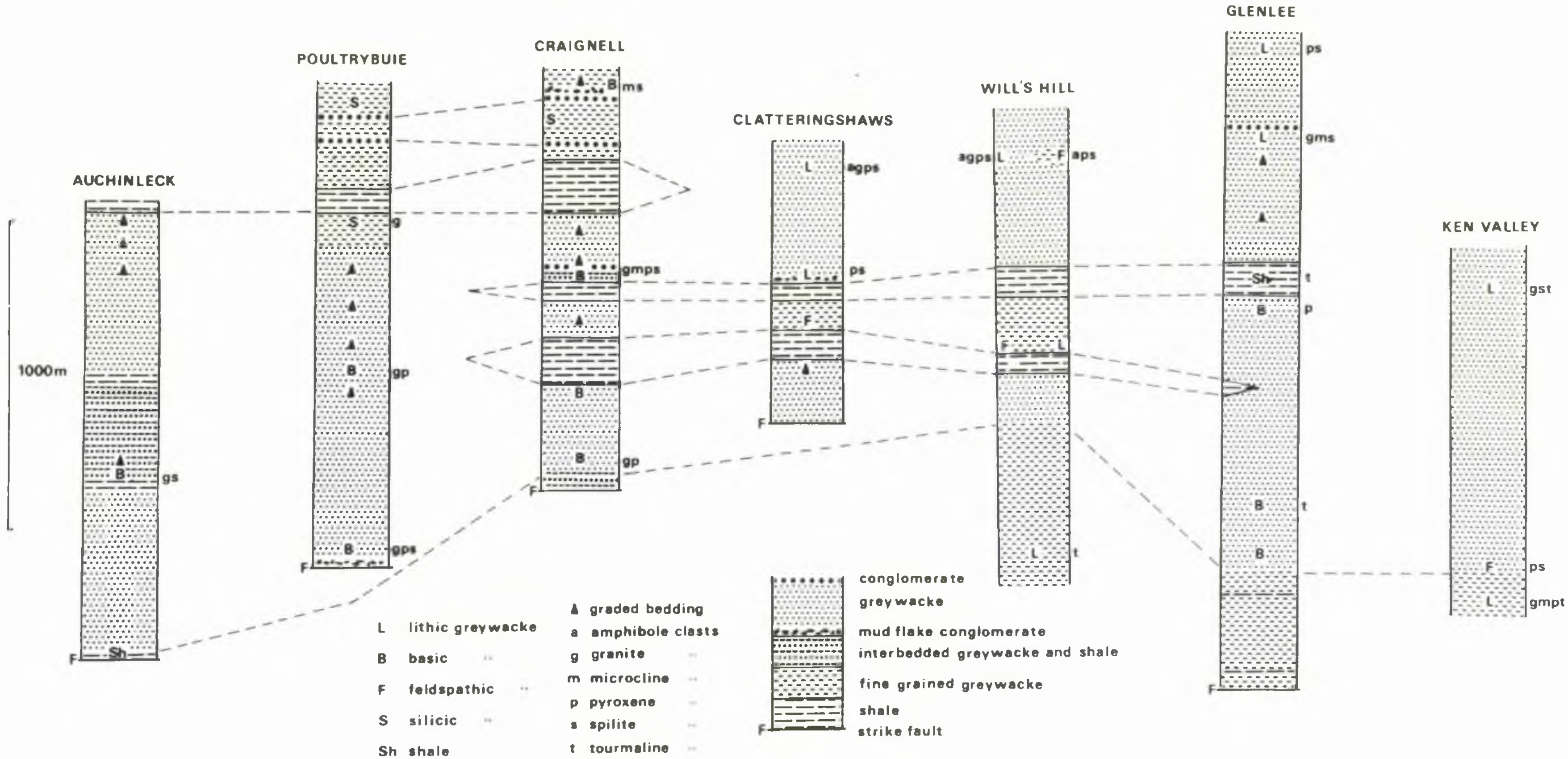
FIG. 19. Correlation of the Craignell Formation across the structural belts in the west of the region from Auchinleck (north) to Moneypool Burn (south). The Knockeans section comprises completely strata of the Knockeans Formation (see Figs. 1 and 18).

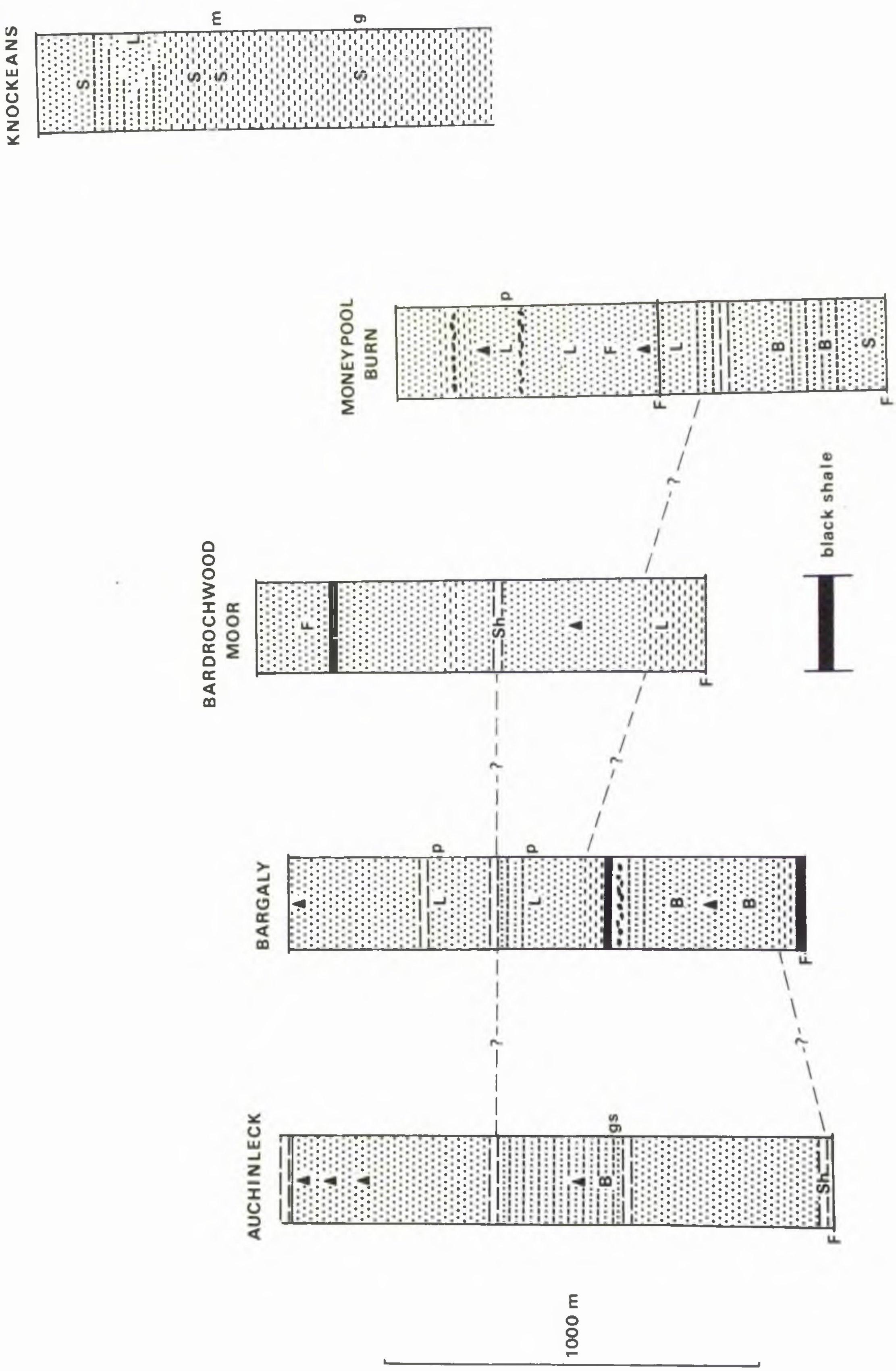

N
A
B
C
D2
D1
E
S
CREE
ESTUARY


A
B
C
S
5 km
GROUP 1 LITHIC
" 2 BASIC
" 3 FELDSPATHIC
" 4 SILICIC
GREYWACKE
" 5 SHALES
" 6 CONTAMINATED SAMPLES

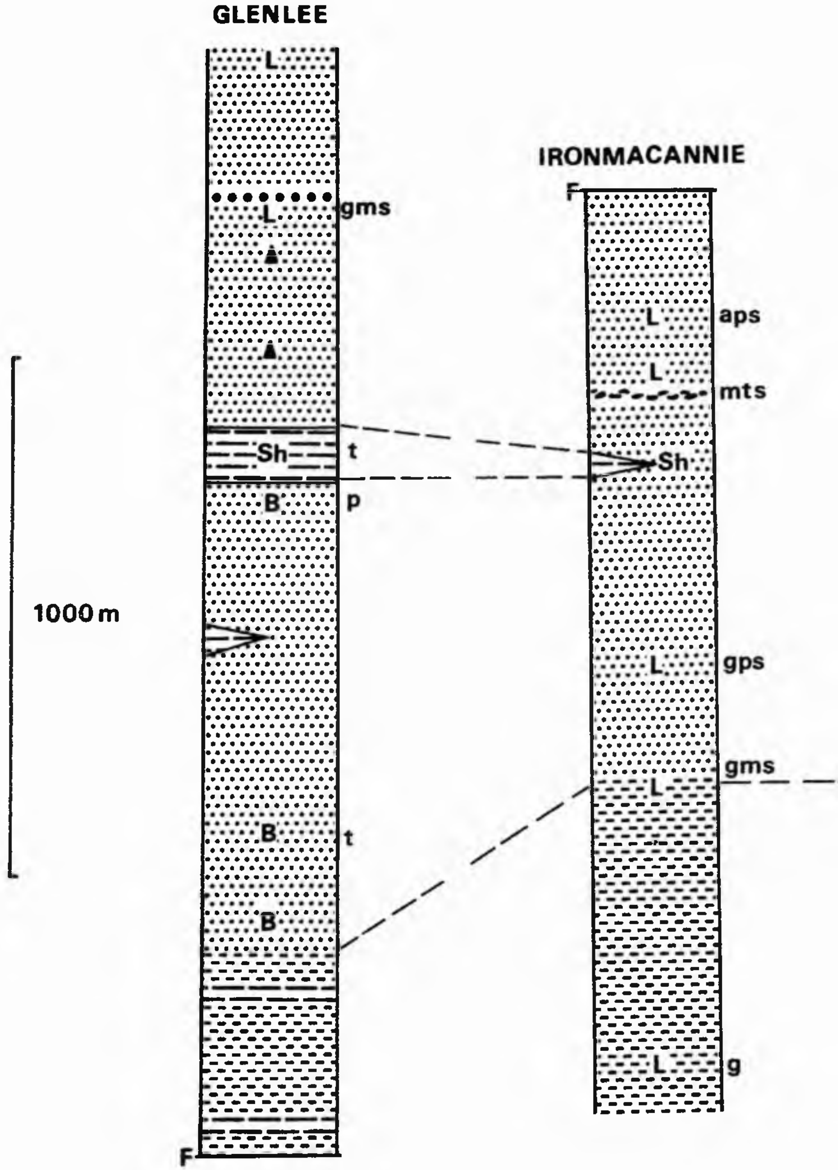

A
37%
37%
13%
13%
B
69%
31%
C
87%
13%
D
11%
26%
44%
19%
E
71%
29%
LITHIC
FELDSPATHIC
BASIC
SILICIC

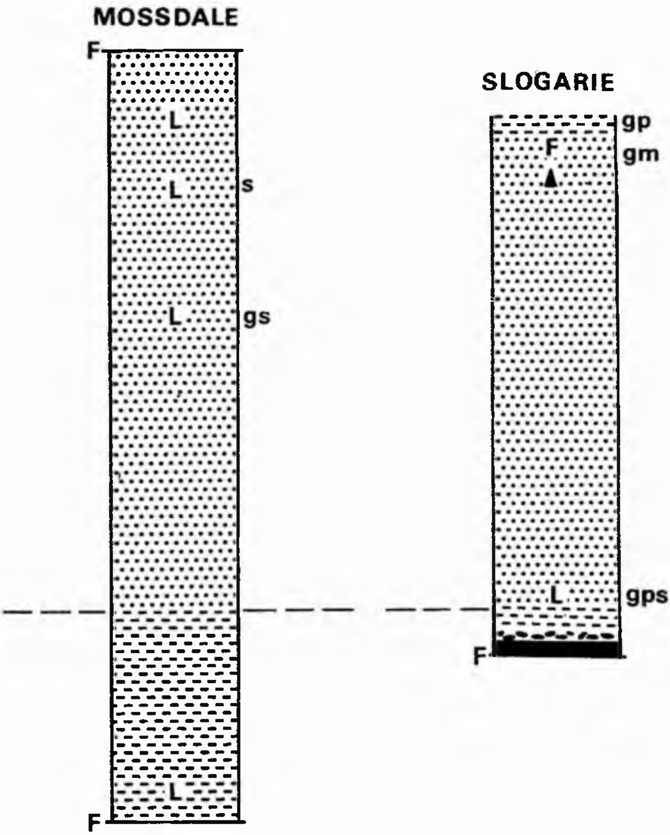

greywacke
shale
silicic
feldspathic
lithic
basic
L
L
B
S
1000 m
10 km
B
L
B
N

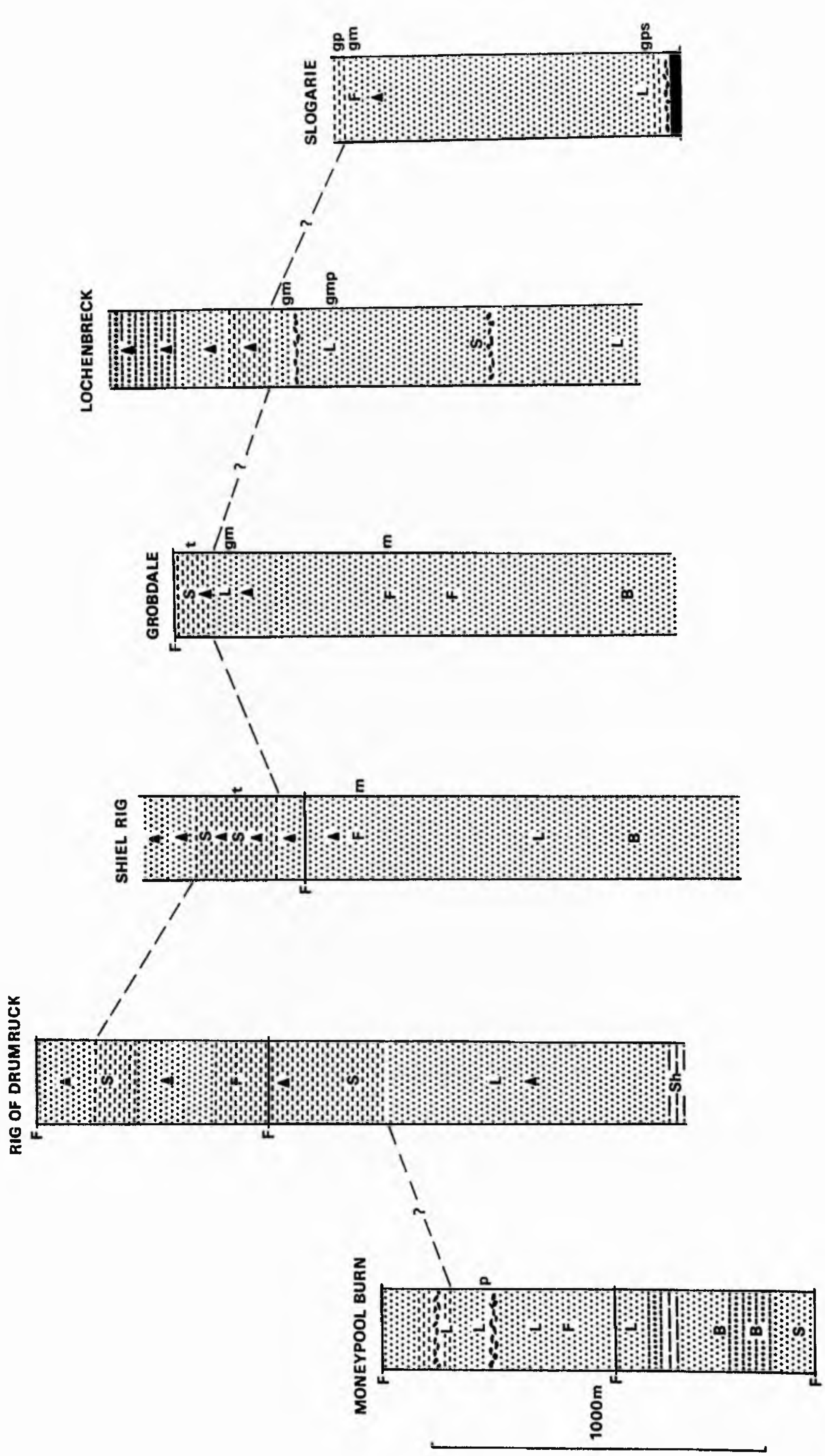

AUCHINLECK
POULTRYBUIE
CRAIGNELL
CLATTERINGSHAWS
WILL'S HILL
GLENLEE
KEN VALLEY
1000m
L lithic greywacke
B basic
F feldspathic
S silicic
Sh shale
graded bedding
a amphibole clasts
g granite
m microcline
p pyroxene
s spilite
t tourmaline
conglomerate
greywacke
mud flake conglomerate
interbedded greywacke and shale
fine grained greywacke
shale
F strike fault

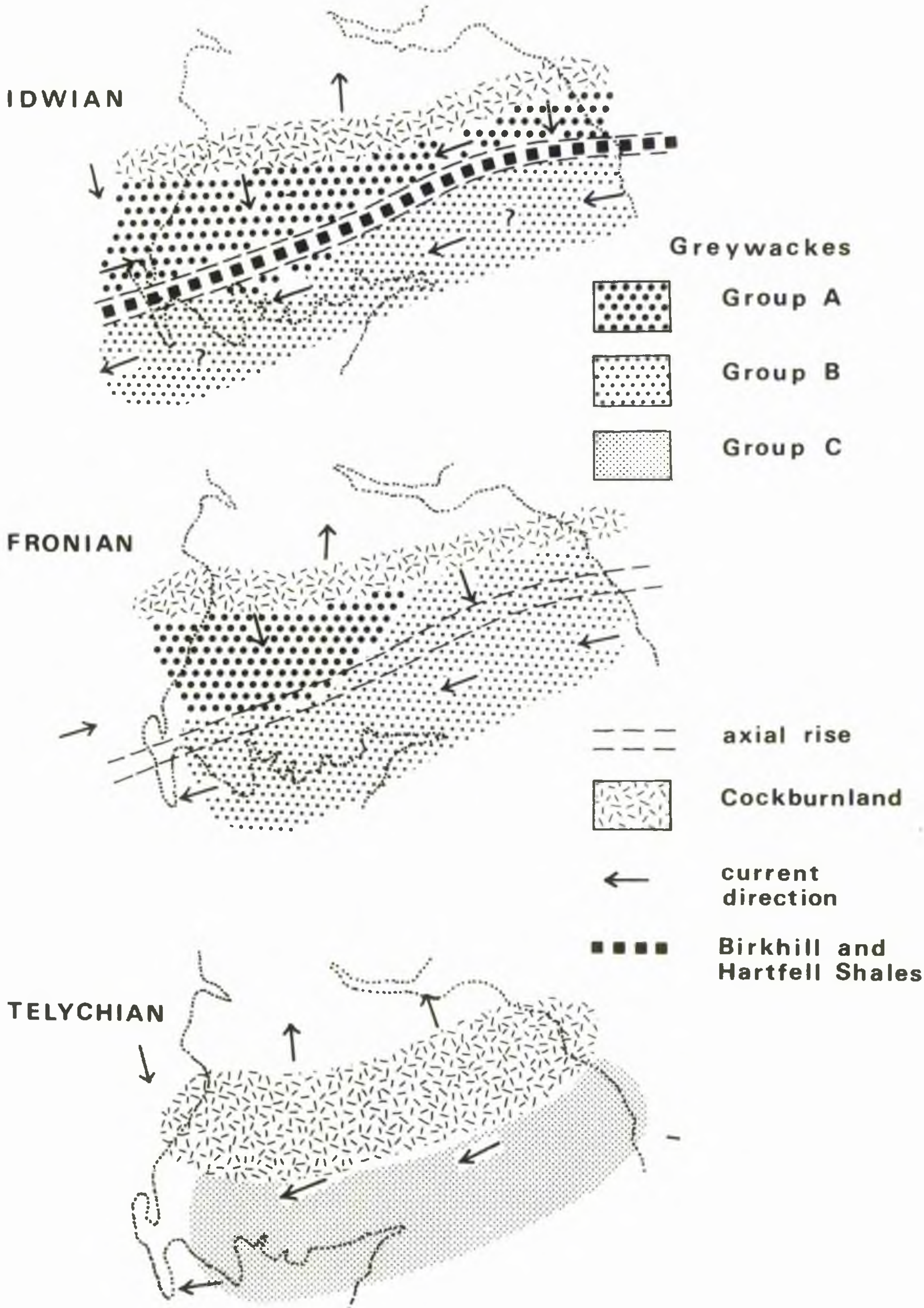

KNOCKEANS
MONEYPOOL BURN
BARDROCHWOOD MOOR
BARGALY
AUCHINLECK
black shale
1000 m

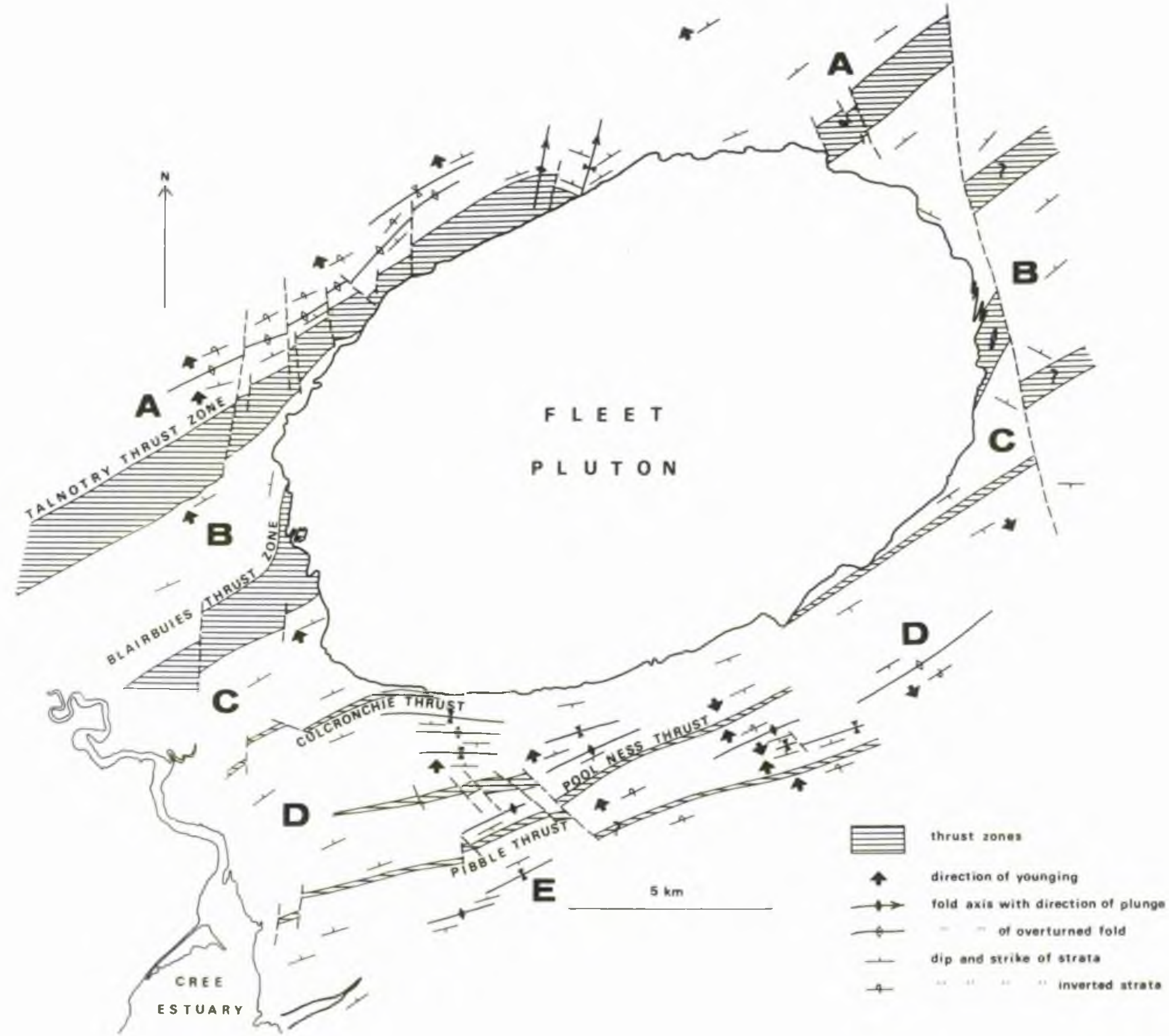
FIGURES 20 - 26.


GLENLEE
IRONMACANNIE
L
gms
Sh
t
B
p
1000 m
aps
mts
gps
g
F

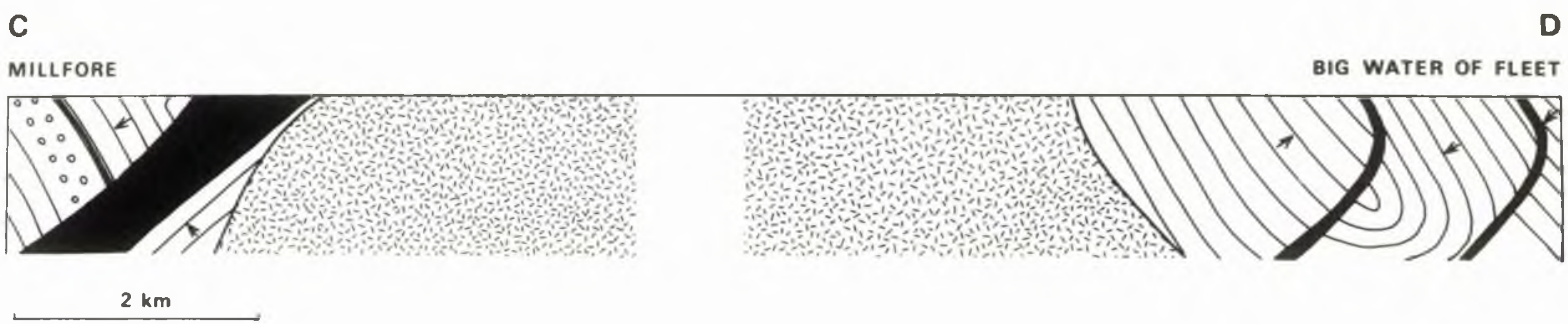

MOSSDALE
F
L
L
s
L
gs
L
F
SLOGARIE
gp
F
gm
L
gps
F

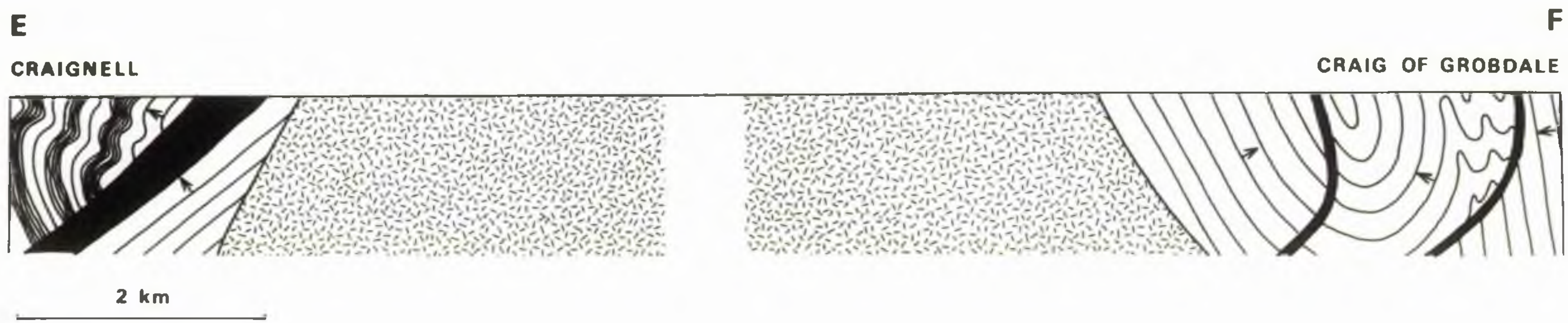

MONEYPOOL BURN
RIG OF DRUMRUCK
SHIEL RIG
GROBDALE
LOCHENBRECK
SLOGARIE
1000m

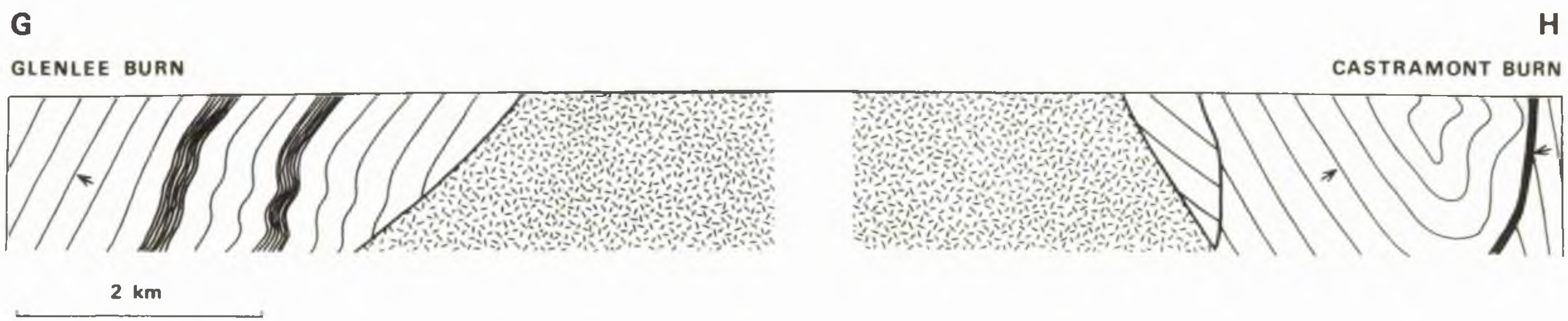

IDWIAN
FRONIAN
TELYCHIAN
Greywackes
Group A
Group B
Group C
axial rise
Cockburnland
current direction
Birkhill and Hartfell Shales


N
FLEET
PLUTON
TALNOTRY THRUST ZONE
BLAIRBUIES THRUST ZONE
COLCRONCHIE THRUST
POOL NESS THRUST
PIBBLE THRUST
A
B
C
D
E
CREE
ESTUARY
5 km
thrust zones
direction of younging
fold axis with direction of plunge
" " of overturned fold
dip and strike of strata
" " " " inverted strata

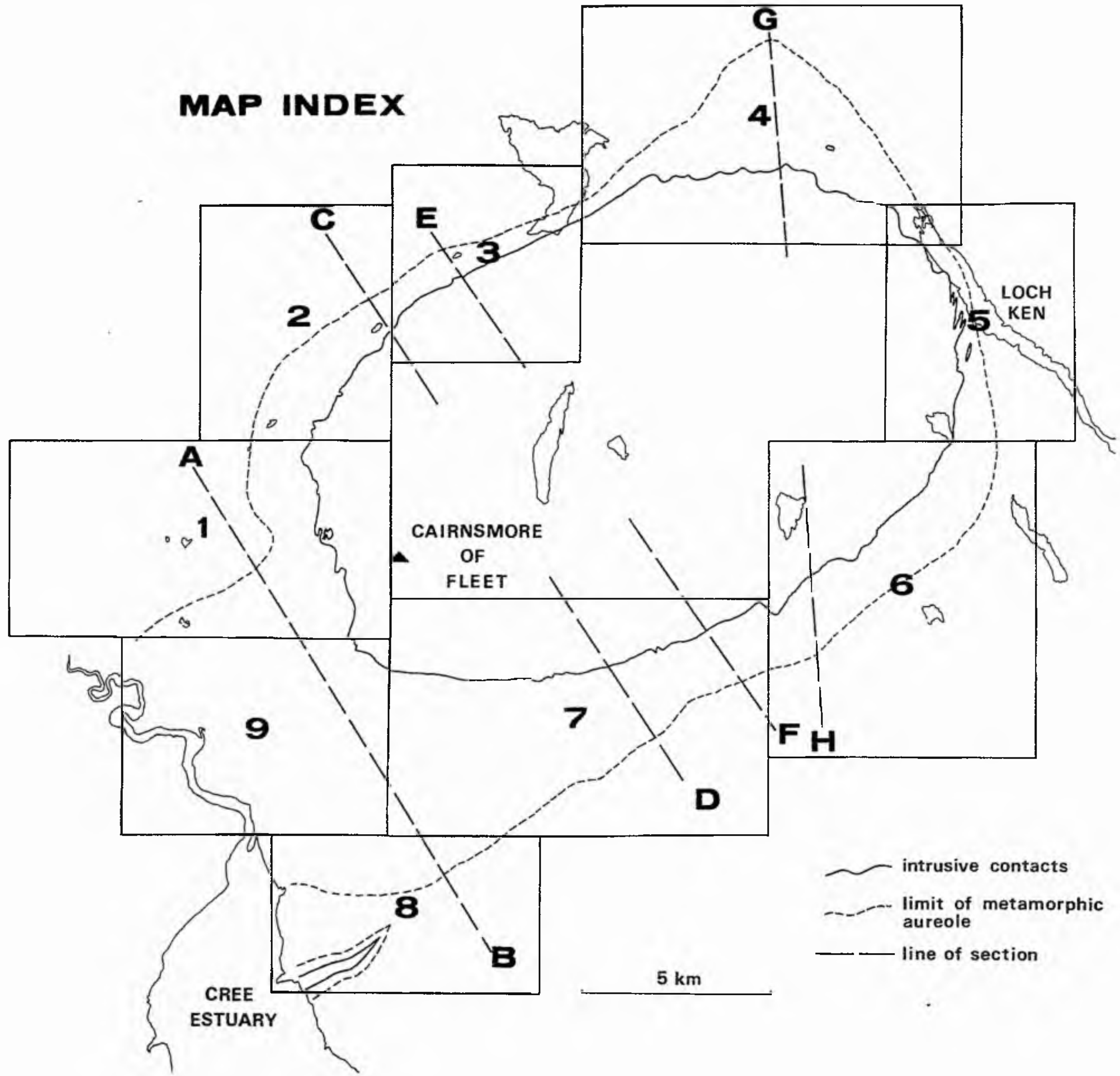

A
PENKILN BURN
B
GLENQUICKEN MOOR
2 km


C
MILLFORE
D
BIG WATER OF FLEET
2 km


E
F
CRAIGNELL
CRAIG OF GROBDALE
2 km


G
H
GLENLEE BURN
CASTRAMONT BURN
2 km

MAP INDEX



G
4
C
E
3
2
LOCH
KEN
5
A
1
CAIRNSMORE
OF
FLEET
6
9
7
F
H
D
8
B
CREE
ESTUARY
intrusive contacts
limit of metamorphic aureole
line of section
5 km

FIGURES 27 - 30.

FIG. 27. A, The structure and orientation of the Talnotry thrust zone, looking southeast.

B, The structure of the Auchinleck-Glenlee belt, looking south east.

FIG. 28. A, Locality 562, structures in black mudstones associated with thrusting. Dashed lines indicate masking of lamination due to silification (Looking WSW. vertical section).

B, Locality 1098, dextral kink band produced by incipient shear, looking east, vertical section.

C, Locality 1110, incipient sinistral wrench (strike-slip) fault (horizontal section).

FIG. 29. Structures in black mudstones adjacent to the Culcronchie Thrust.

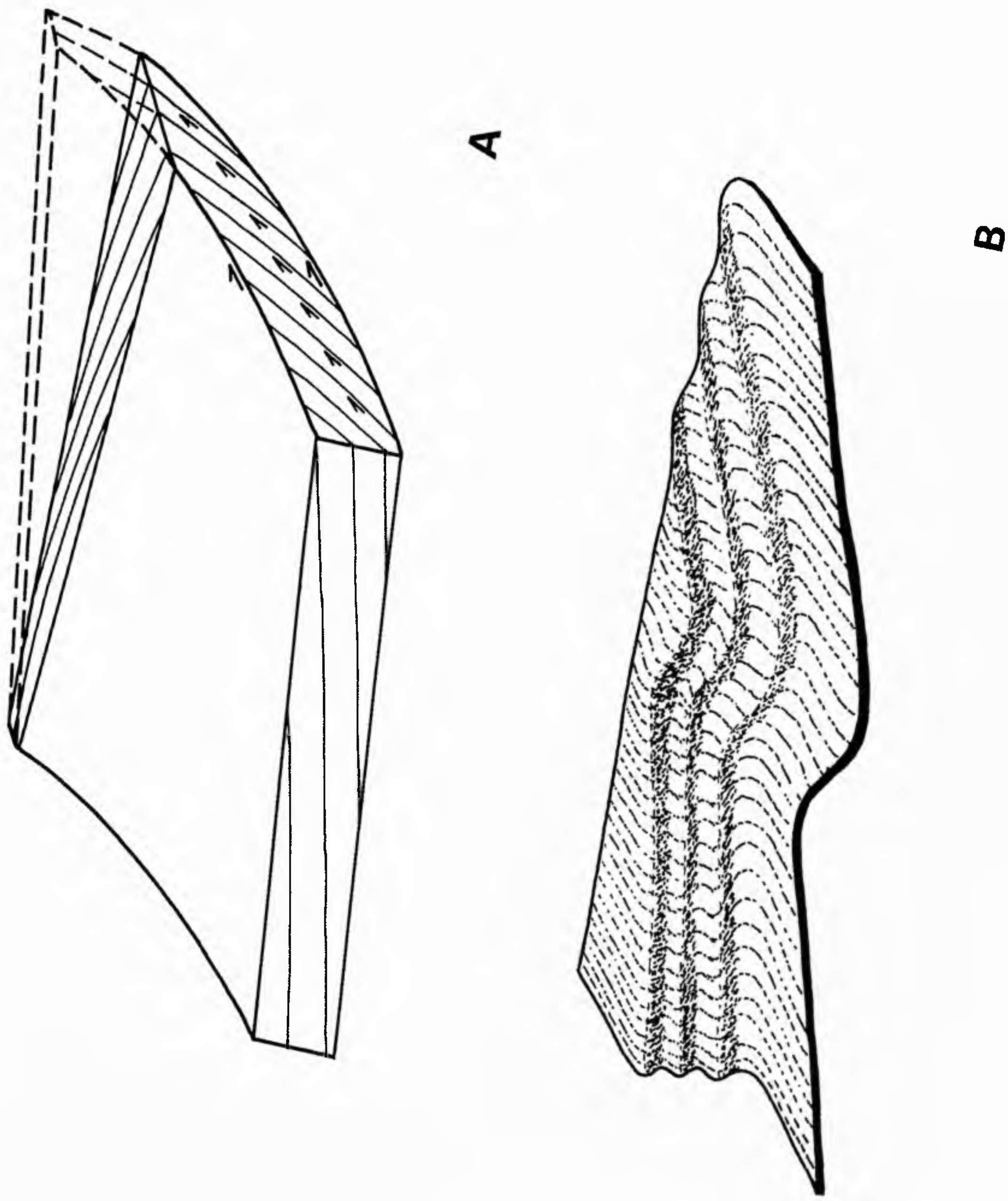
A, Locality 684, mullion in black mudstone above a thin band of greywacke.

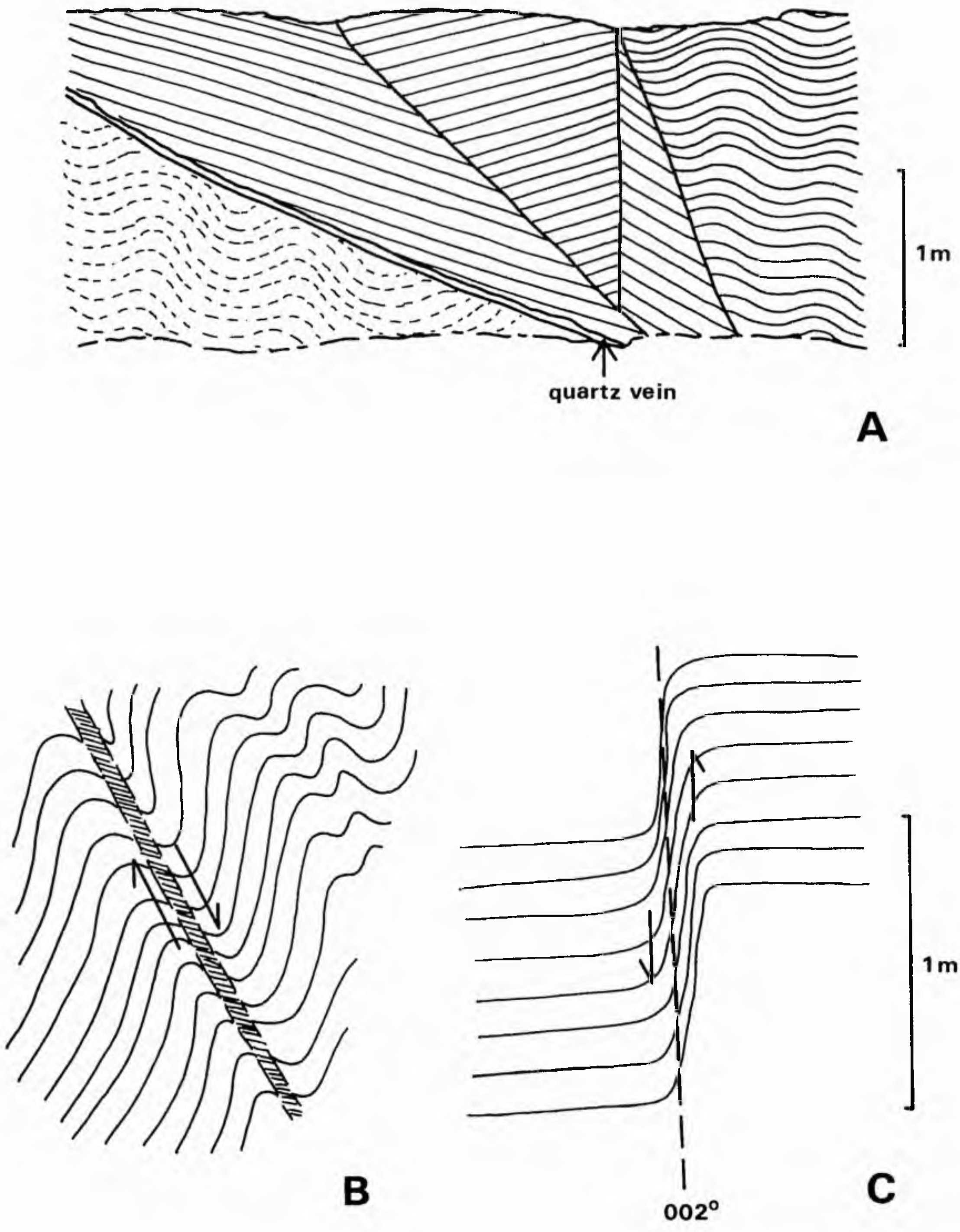
B, Locality 683, faulting and puckering of black mudstones; closely spaced lines indicate zone of crushing, looking west.

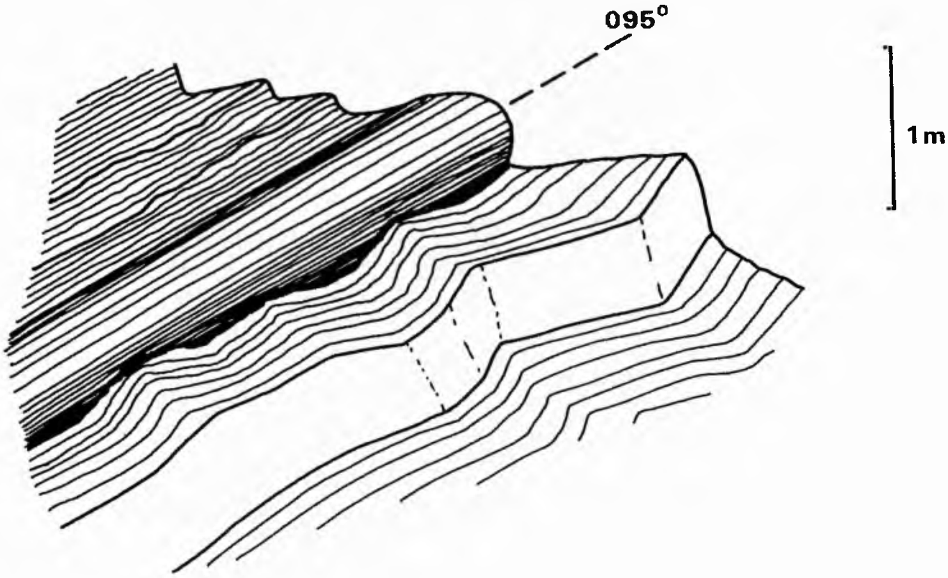
FIG. 30. A, N.-S. section across the refolded (F1) syncline at Derrygown Burn, Barholm-Drumglass belt; a, refolded F1 axis; b, F_4 axes.

B, Faulted black mudstone (a) and greywacke (b) succession thrust over greywacke, Talnotry thrust zone, loçality 841, looking east (F = fault, T = thrust).

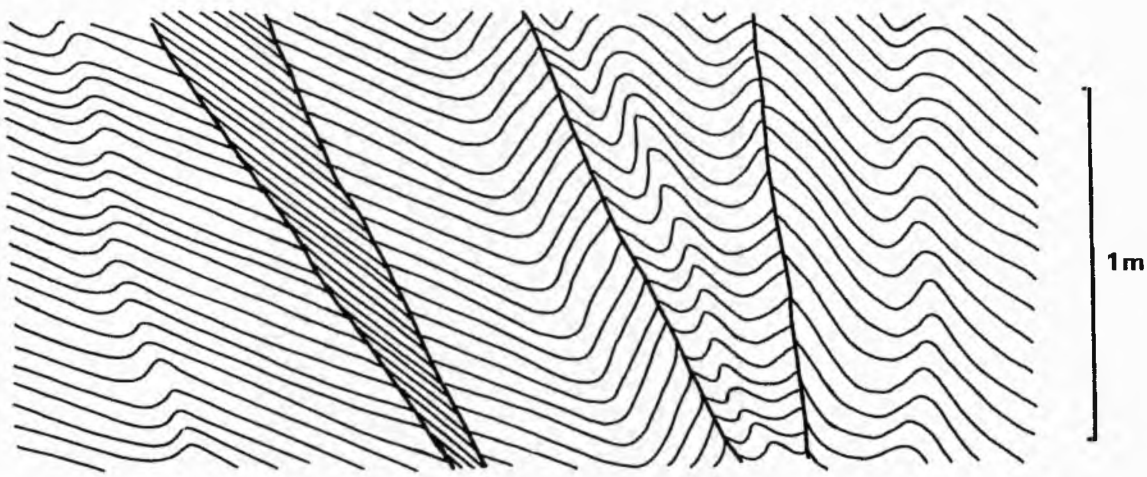
C, Thrust within Pibble thrust zone, locality 841, looking east; a, drag folded greywacke; b, black mudstone; c, crushed and contorted black mudstone; T, thrust. d?.


A
B

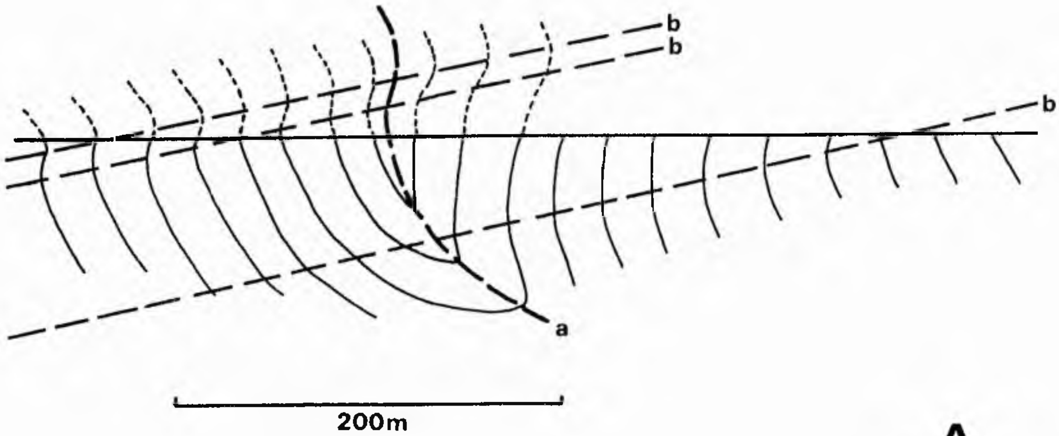

1m
quartz vein
A
B
1m
002°
C



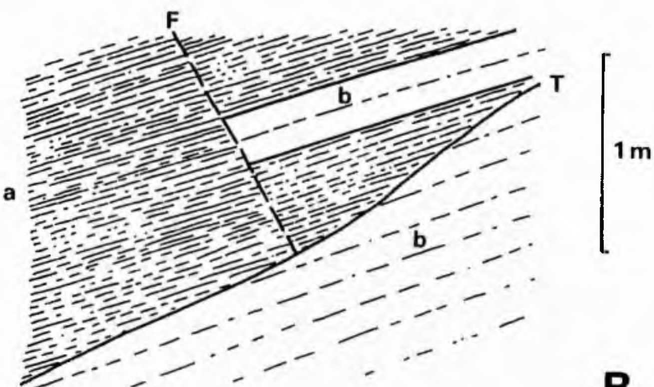
A



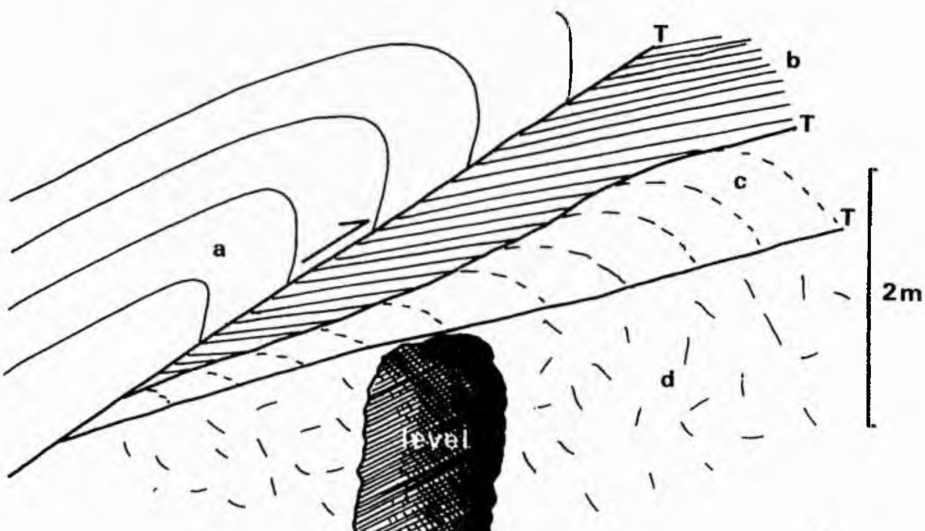
B



A

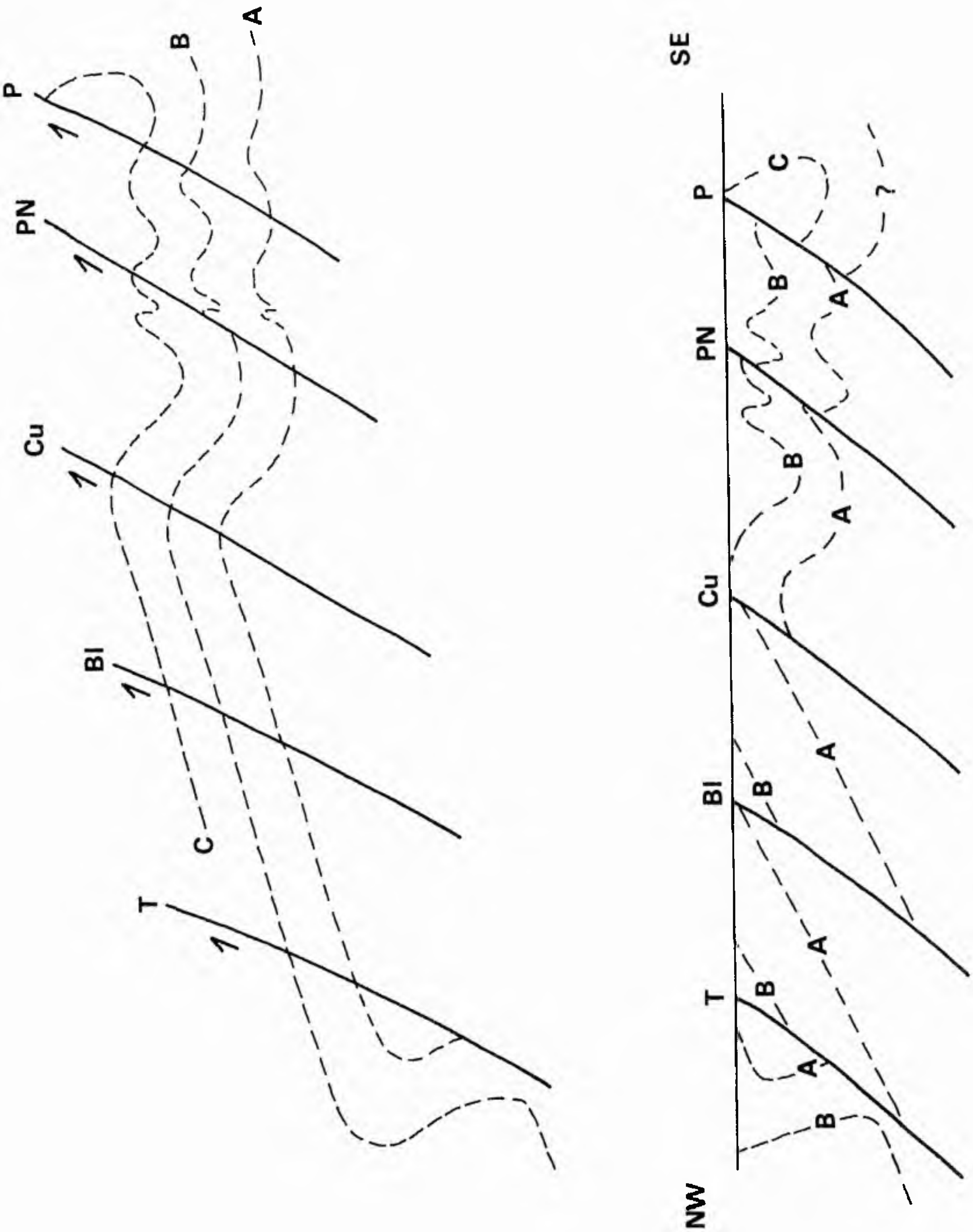


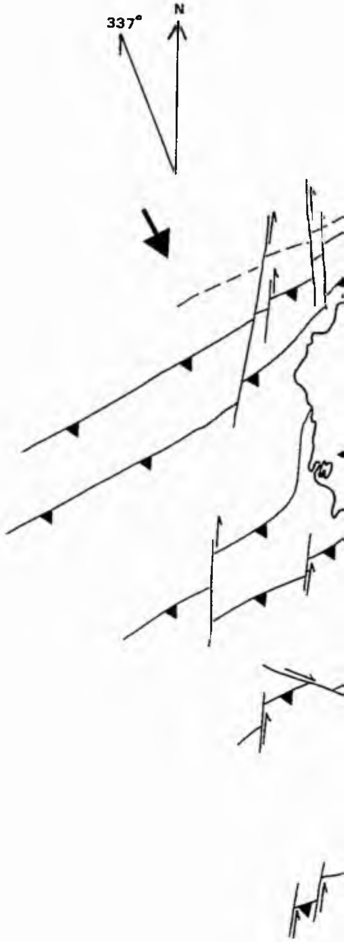
B

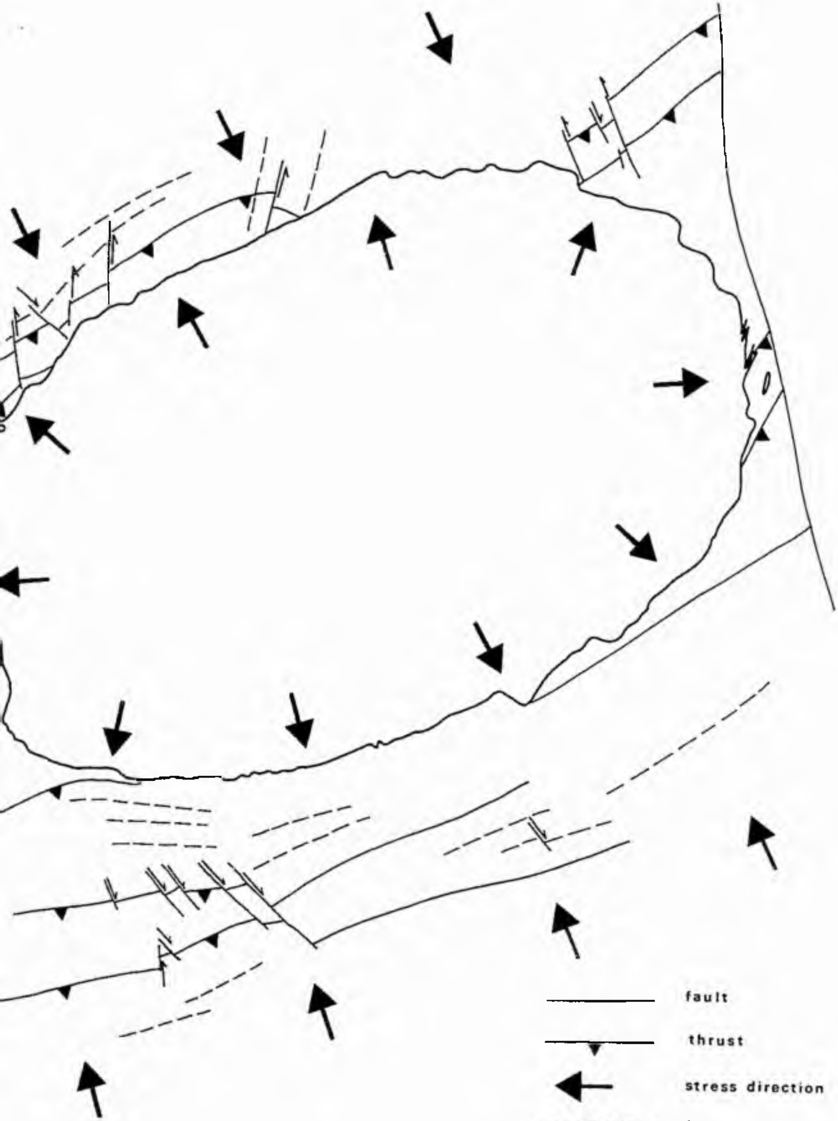


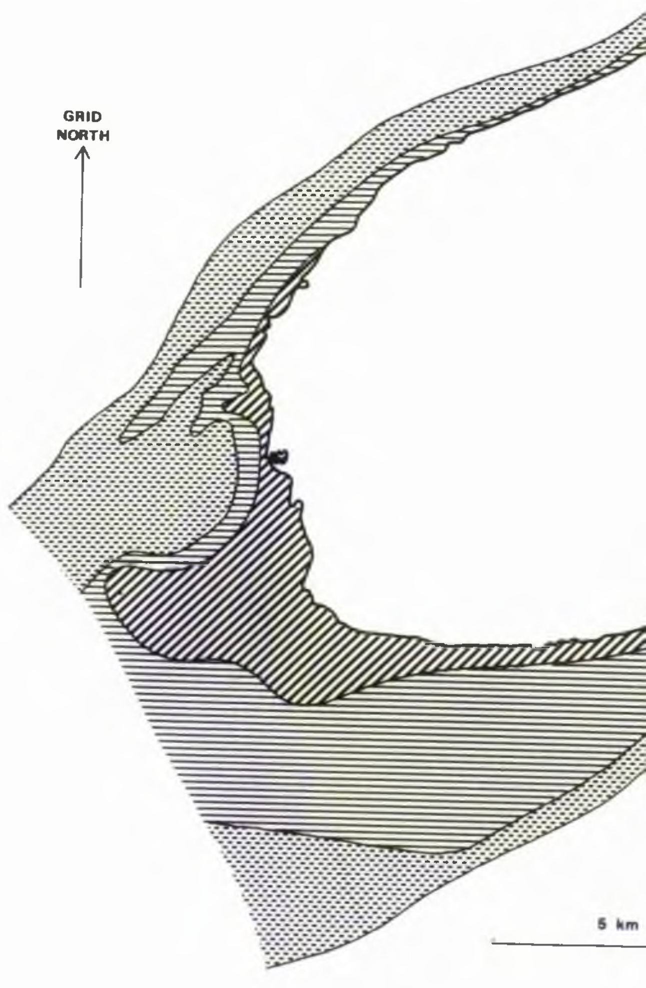
C

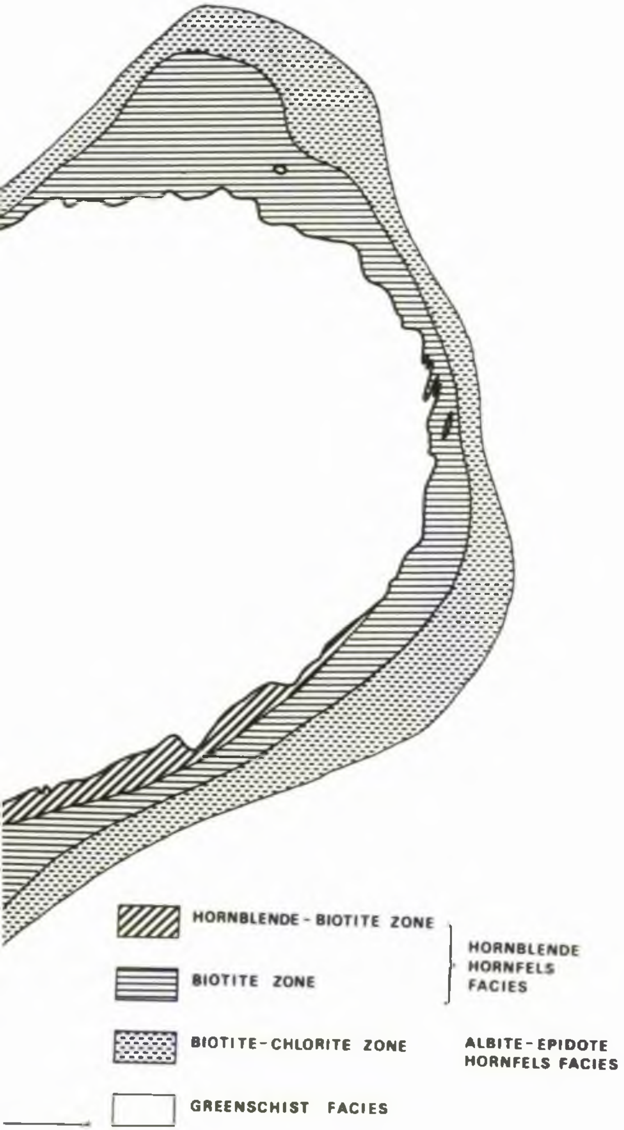
FIGURES 31 - 36.

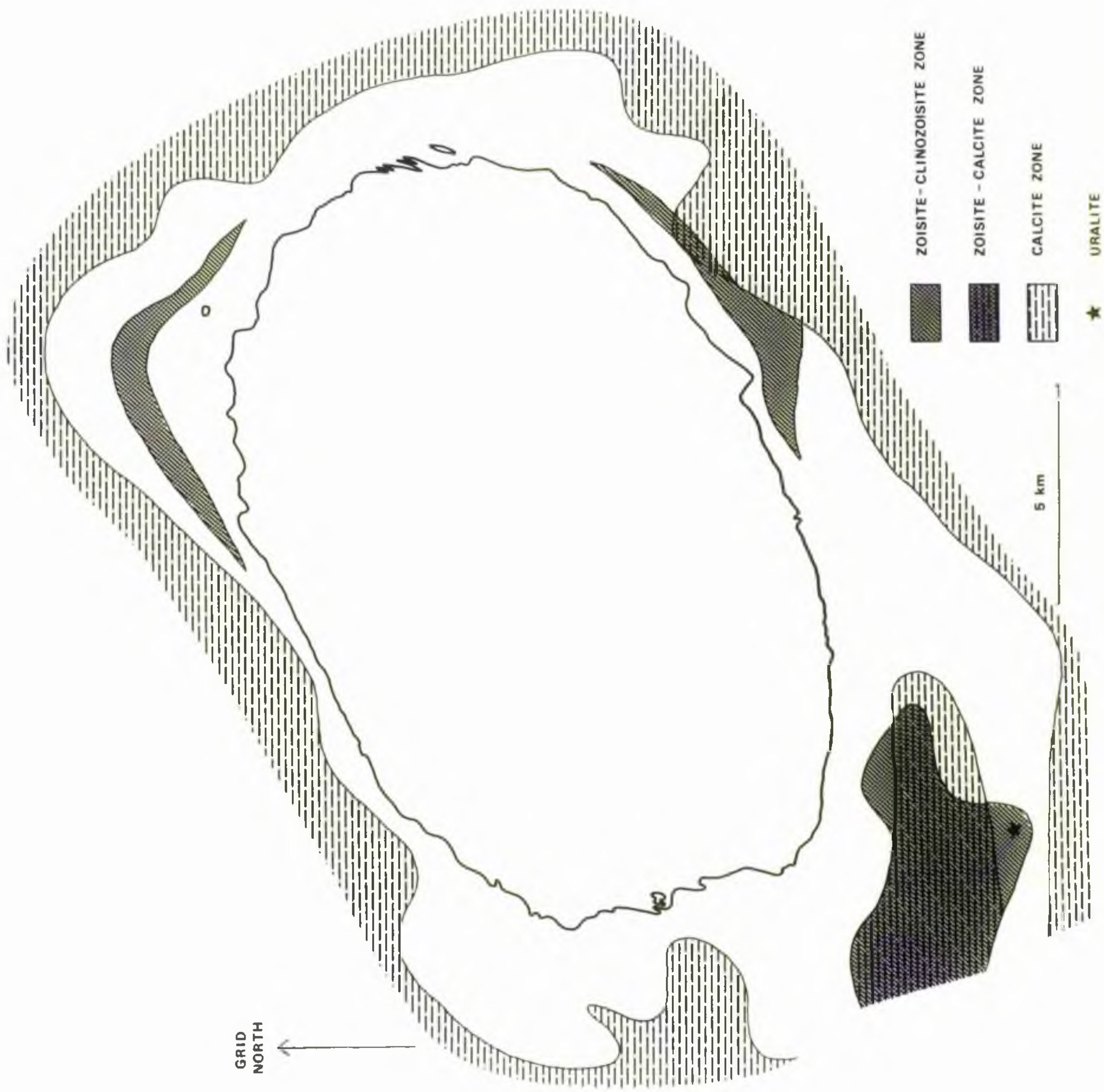

P
PN
Cu
Bl
T
A
B
C
NW
SE
?

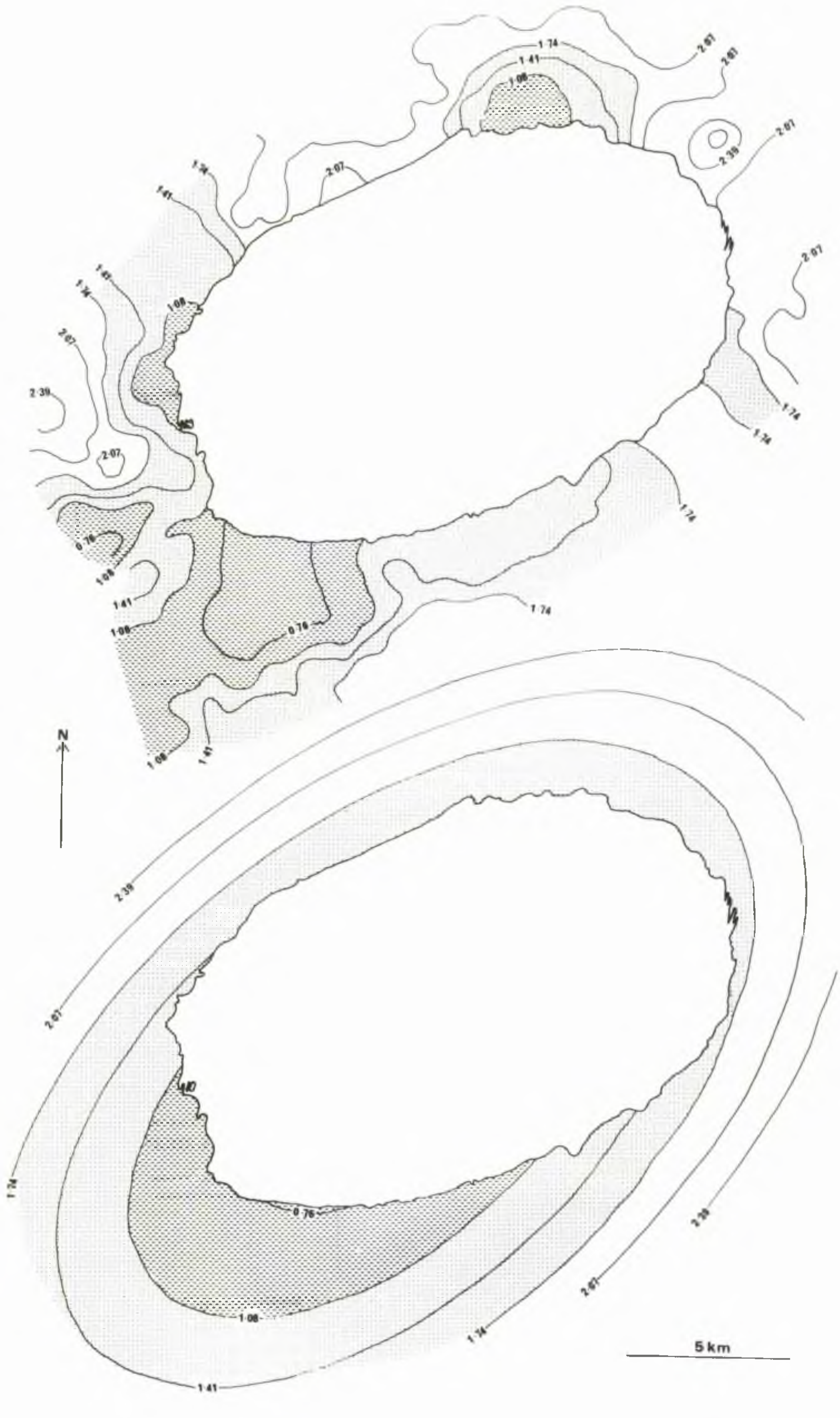

337°
N


fault
thrust
stress direction
fold axis


GRID
NORTH
5 km


HORNBLENDE - BIOTITE ZONE
BIOTITE ZONE
HORNBLENDE HORNFELS FACIES
BIOTITE-CHLORITE ZONE
ALBITE-EPIDOTE HORNFELS FACIES
GREENSCHIST FACIES


ZOISITE - CLINOZOISITE ZONE
ZOISITE - CALCITE ZONE
CALCITE ZONE
URALITE
5 km
GRID NORTH



N
5 km

Map Key

greywacke

thick conglomerate horizons

thick grey shale horizons

dark grey-black shales

black shales

plutonic igneous rocks

minor intrusive rocks of dioritic composition unless:

Pg pegmatite

G microgranite

mineral veins

Cu, chalcopyrite; Ni, niccolite;

Zn, sphalerite; Co, cobaltite;

Pb, galena; Fe, pyrrhotite;

As, arsenopyrite; Q, quartz

minor quartz veins

upright fold axes

plunging anticline

syncline

overturned fold axes

anticline

syncline

bedding

trend

inverted

dip and strike

normal

vertical

faults

dextral wrench

sinistral wrench

thrust or reverse, peck on downthrow side

H Hartfell lithology

B Birkhill lithology

settlements

FIGURES 37 - 42.

FIG. 37. Distribution of the geophysically predicted subsurface topography of the granite batholith beneath the western part of the Southern Uplands (Alsayegh, 1975) compared with the positions of mineralised localities (●).

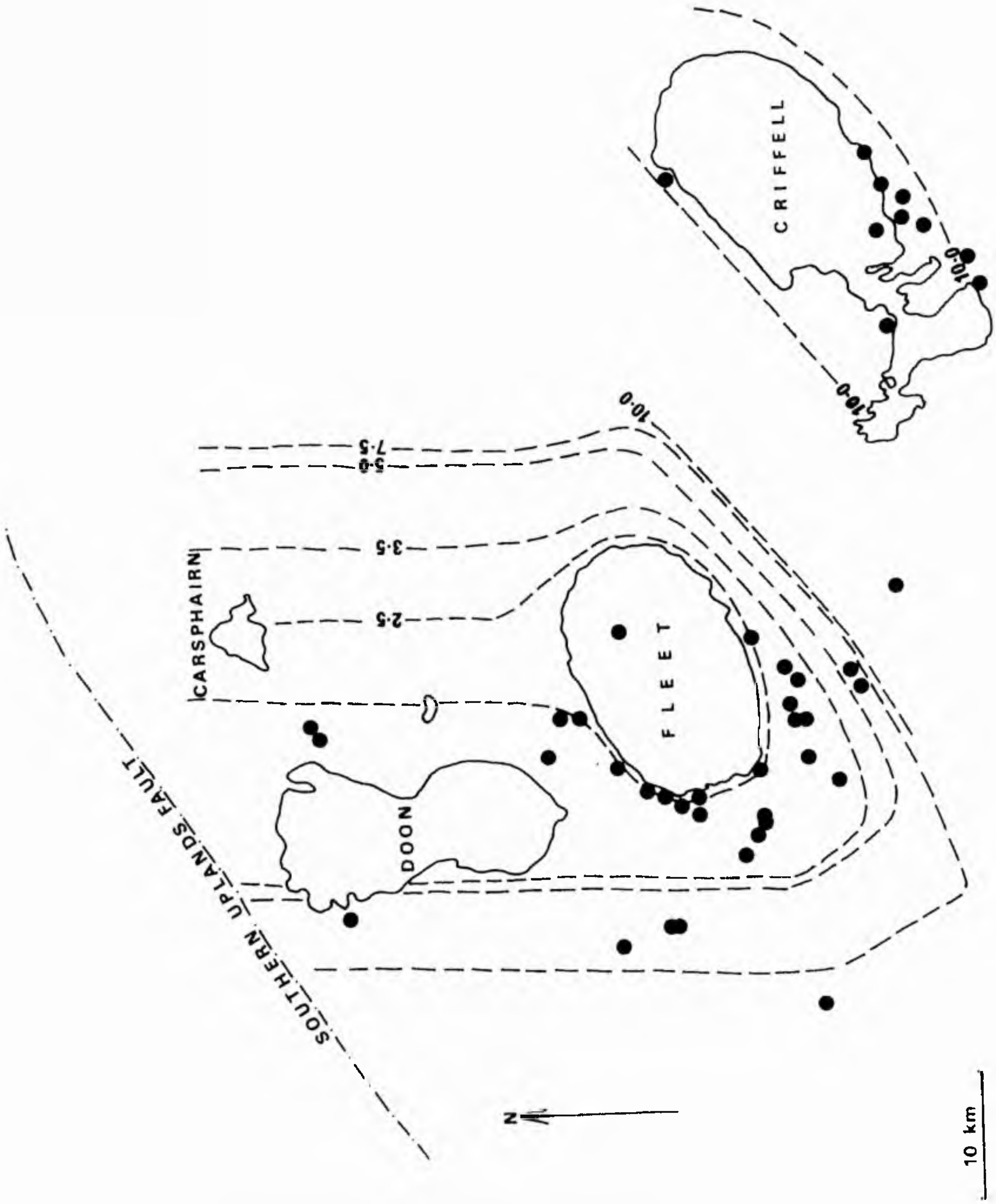
FIG. 38. Distribution of the different petrological types of granite samples. Lithological boundaries are from Parslow (1964).

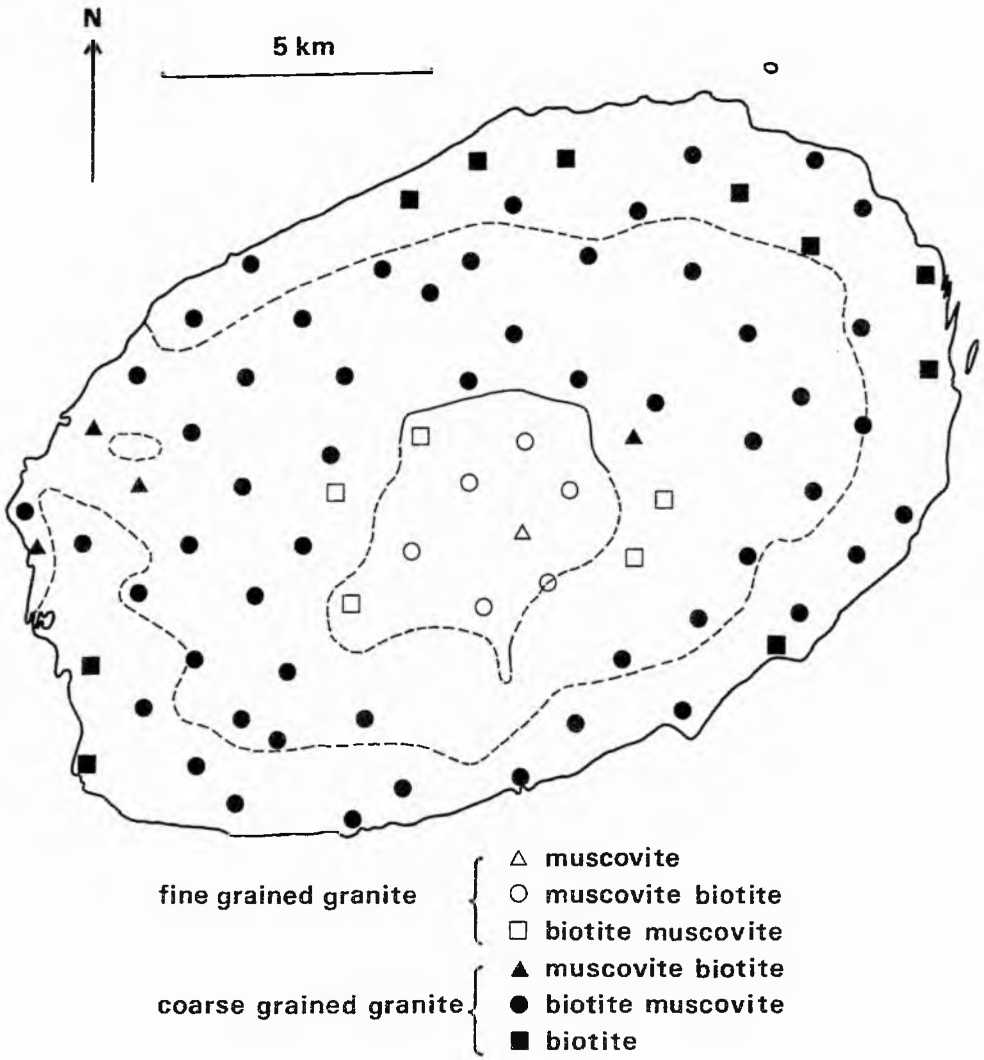
FIG. 39. Mineralogical banding developed as a result of granitization of a sedimentary raft, locality 519 (56312712).

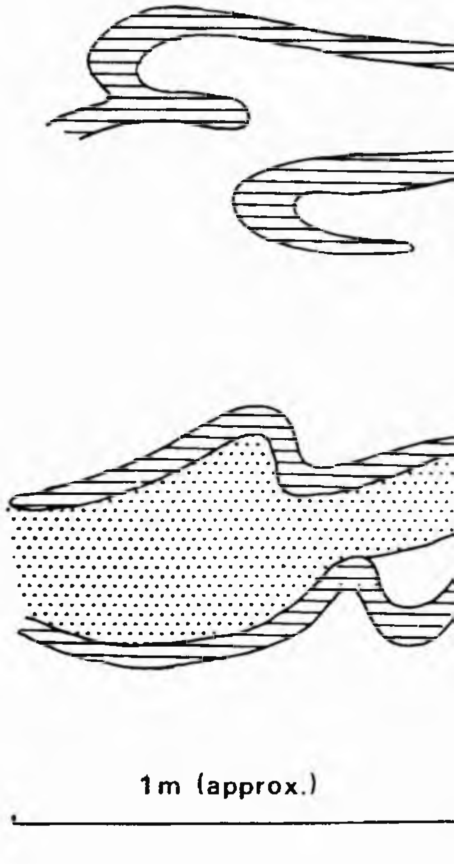
FIG. 40. Chemical classification (from cluster analysis) of the granite samples. 1-12 are samples from which minerals have been separated.

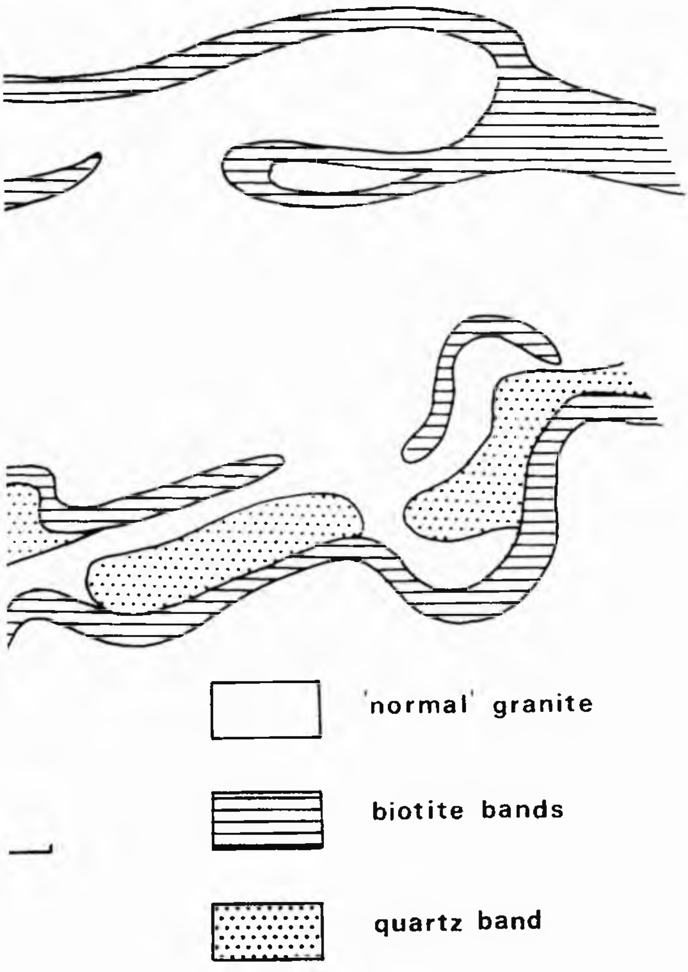
FIG. 41. Dendrogram from cluster analysis of granite samples. Inset graph indicates large increase in fusion coefficient after fusion of 4 clusters (cut off). Symbols refer to petrological facies, see Figure 38.

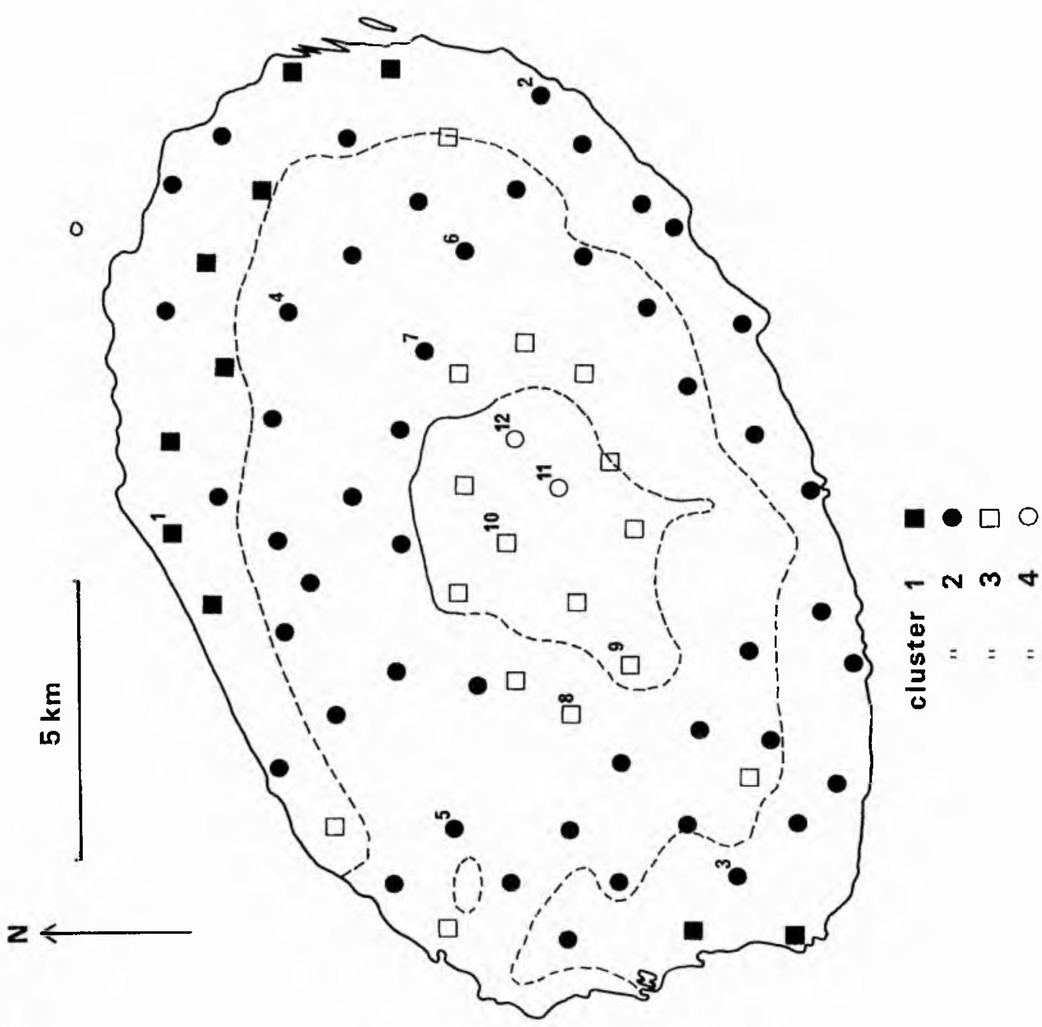
FIG. 42. Variation diagrams of the means of chemical variables versus the mean Differentiation Index of clusters 1-4. Standard deviations may be obtained from tables 11 and 12.

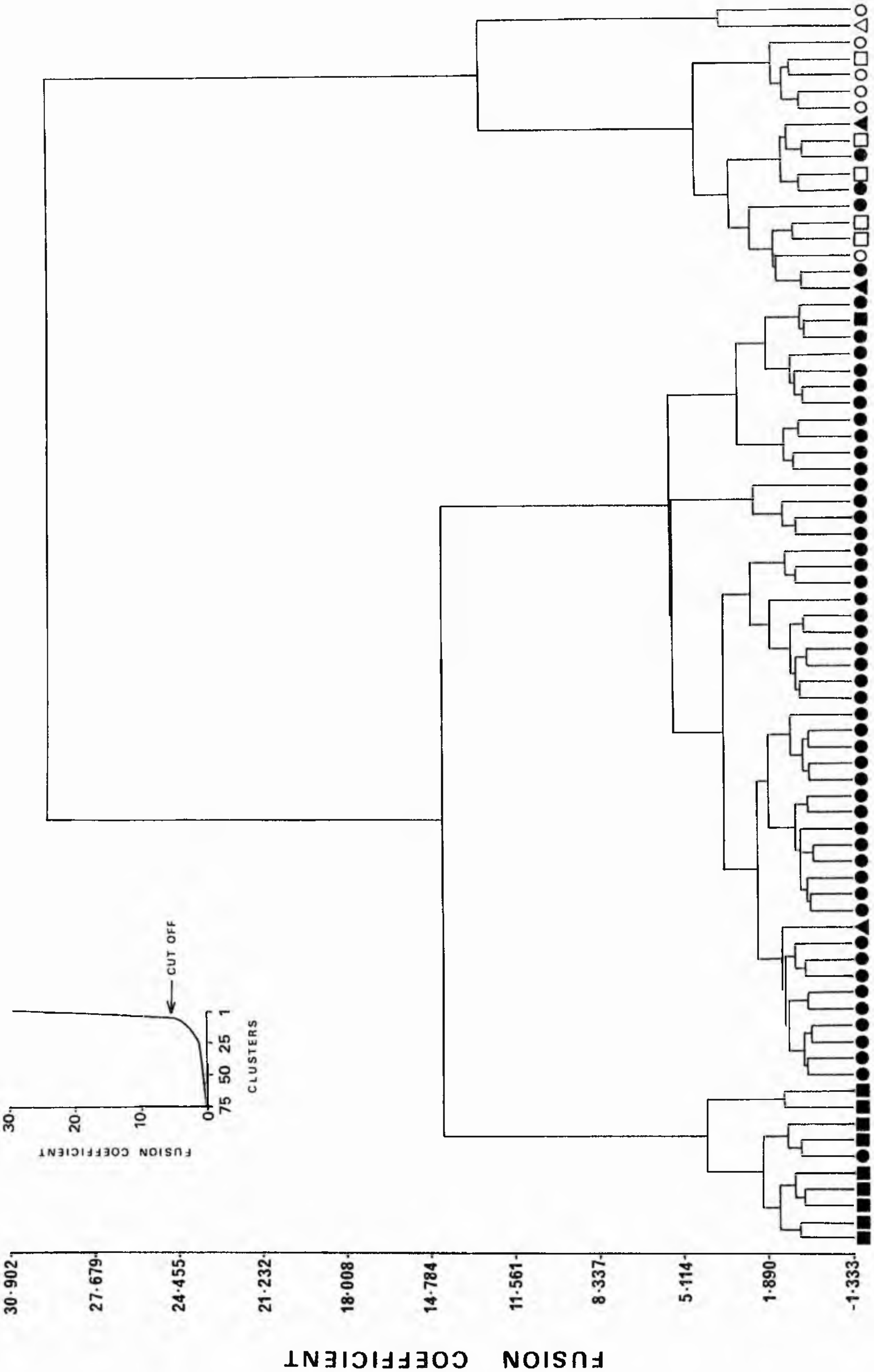

CRIFFELL
FLEET
DOON
CARSPHAIRN
SOUTHERN UPLANDS FAULT
10·0
10·0
10·0
7·5
5·0
3·5
2·5
N
10 km

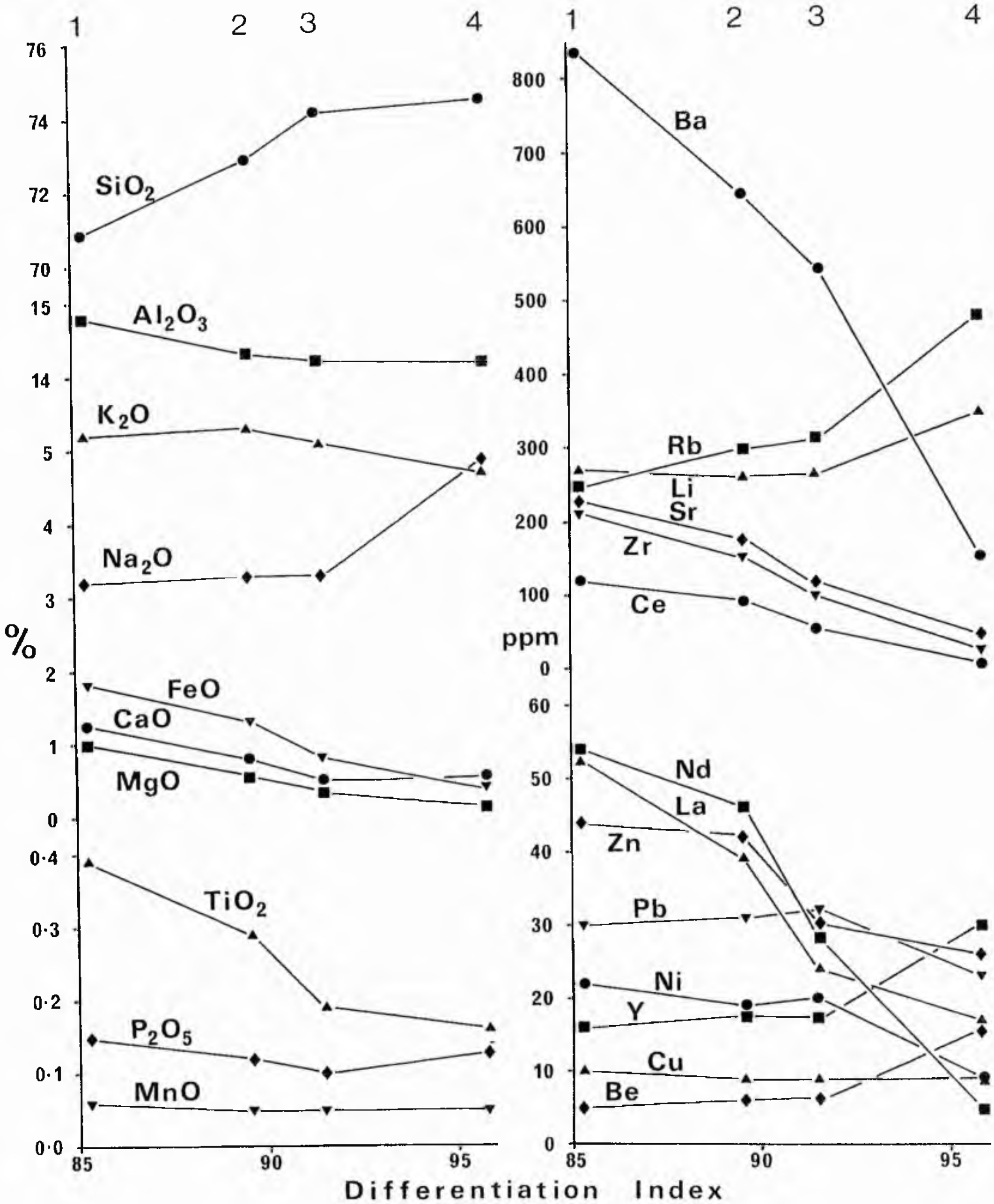

N
5 km
fine grained granite
muscovite
muscovite biotite
biotite muscovite
coarse grained granite
muscovite biotite
biotite muscovite
biotite


1m (approx.)


'normal' granite
biotite bands
quartz band


N
5 km
cluster 1
" 2
" 3
" 4
1
2
3
4
5
6
7
8
9
10
11
12


30·902
27·679
24·455
21·232
18·008
14·784
11·561
8·337
5·114
1·890
-1·333
FUSION COEFFICIENT
30
20
10
0
FUSION COEFFICIENT
75
50
25
1
CLUSTERS
CUT OFF



1
2
3
4
SiO2
Al2O3
K2O
Na2O
FeO
CaO
MgO
TiO2
P2O5
MnO
%
Ba
Rb
Li
Sr
Zr
Ce
ppm
Nd
La
Zn
Pb
Ni
Y
Cu
Be
Differentiation Index

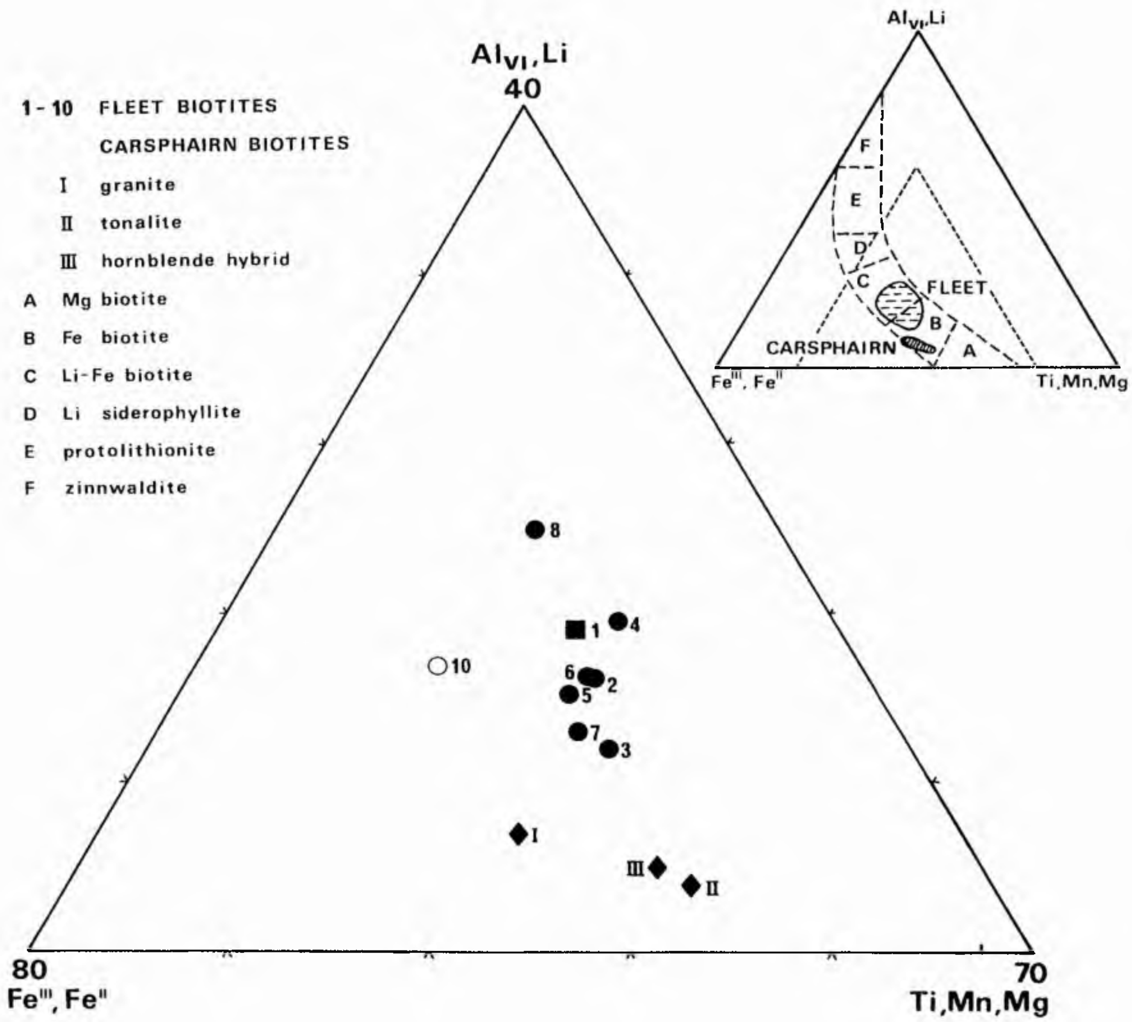
FIGURES 43 - 46.

FIG. 43. Ternary diagrams of octahedral Al_{vi}, Li - Fe^{3+}, Fe^{2+} - Ti^{4+}, Mn^{2+}, Mg^{2+} in biotites. Symbols refer to petrological type of host rock from Figure 38; ◆ = Cairnsmore of Carsphairn samples (Deer, 1936). The inset ternary diagram compares the position of biotites from Fleet and Carsphairn with those from the Erzgebirge (Lange et al., 1972). The dotted triangle in the inset plot indicates the position of the larger triangle (sample numbers from Figure 40).

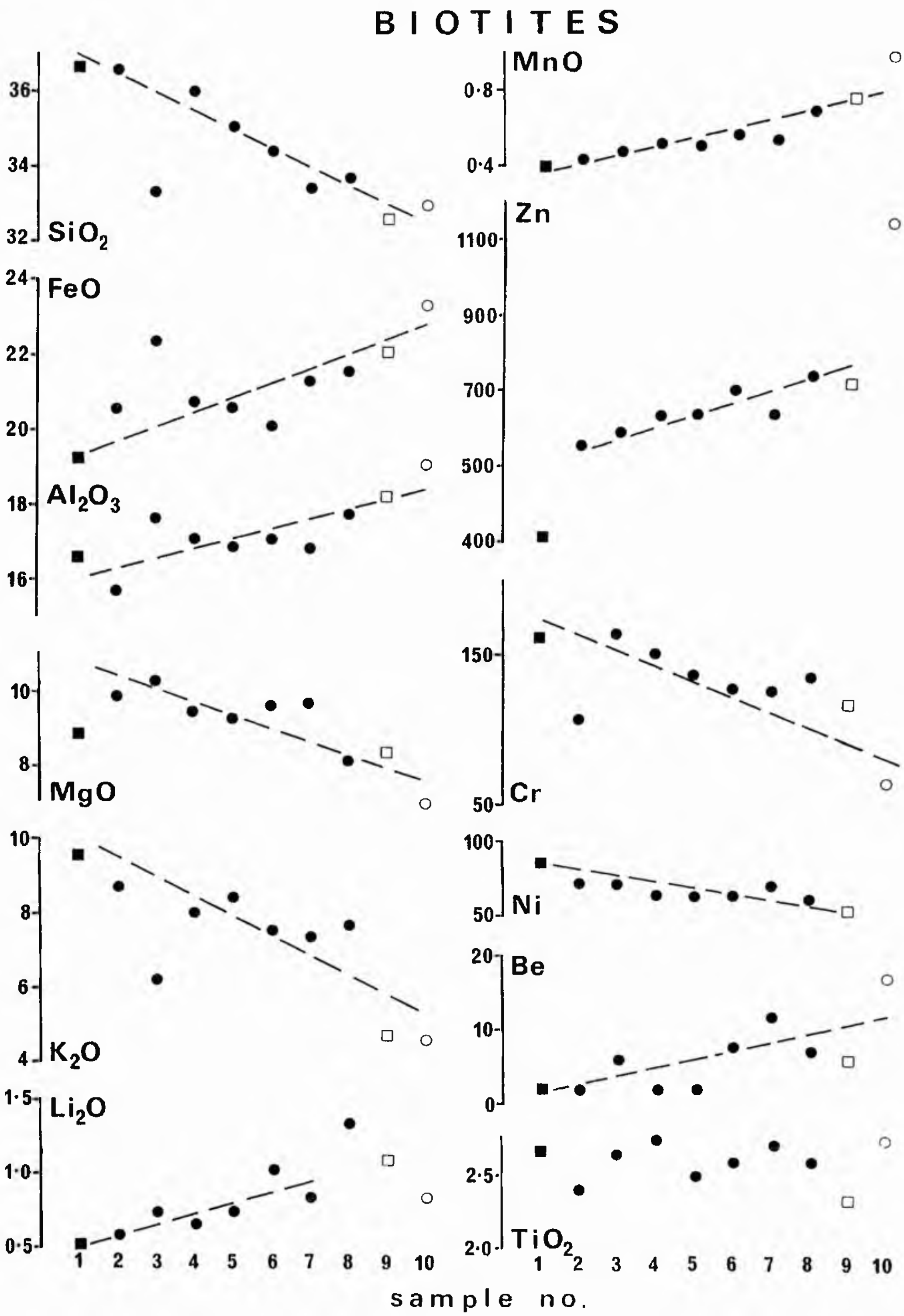
FIG. 44. Chemical variations in biotite from samples 1 to 10 (Fig. 40).

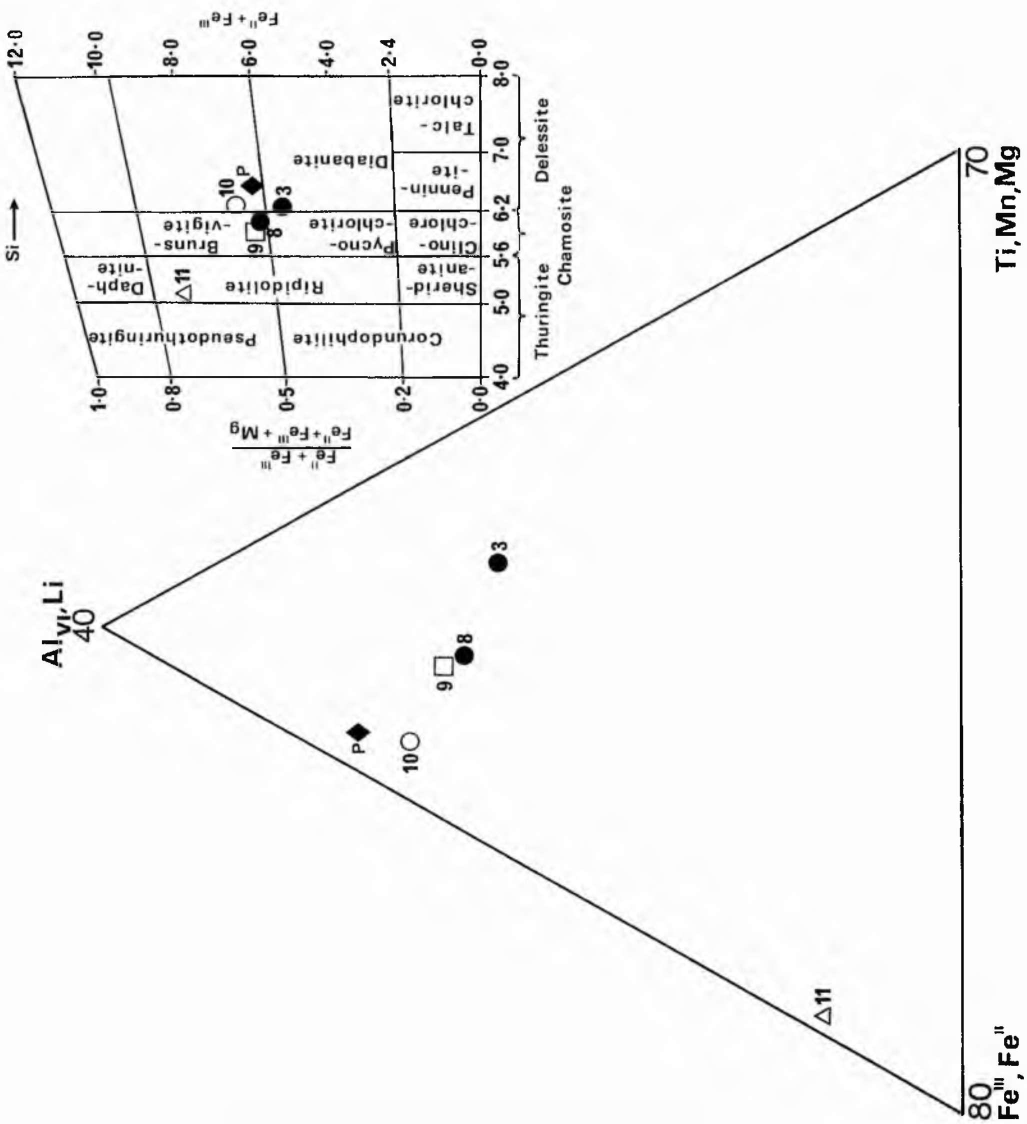
FIG. 45. Ternary diagram of octahedral Al_{vi}, Li - Fe^{3+}, Fe^{2+} - Ti^{4+}, Mn^{2+}, Mg^{2+} in chlorites. Symbols from Fig. 38, sample numbers from Fig. 40. P = pegmatite 73/517C. The inset diagram is the chlorite classification scheme of Hey (1954).

FIG. 46. Chemical variations in chlorites from samples 3-11 (Fig. 40).

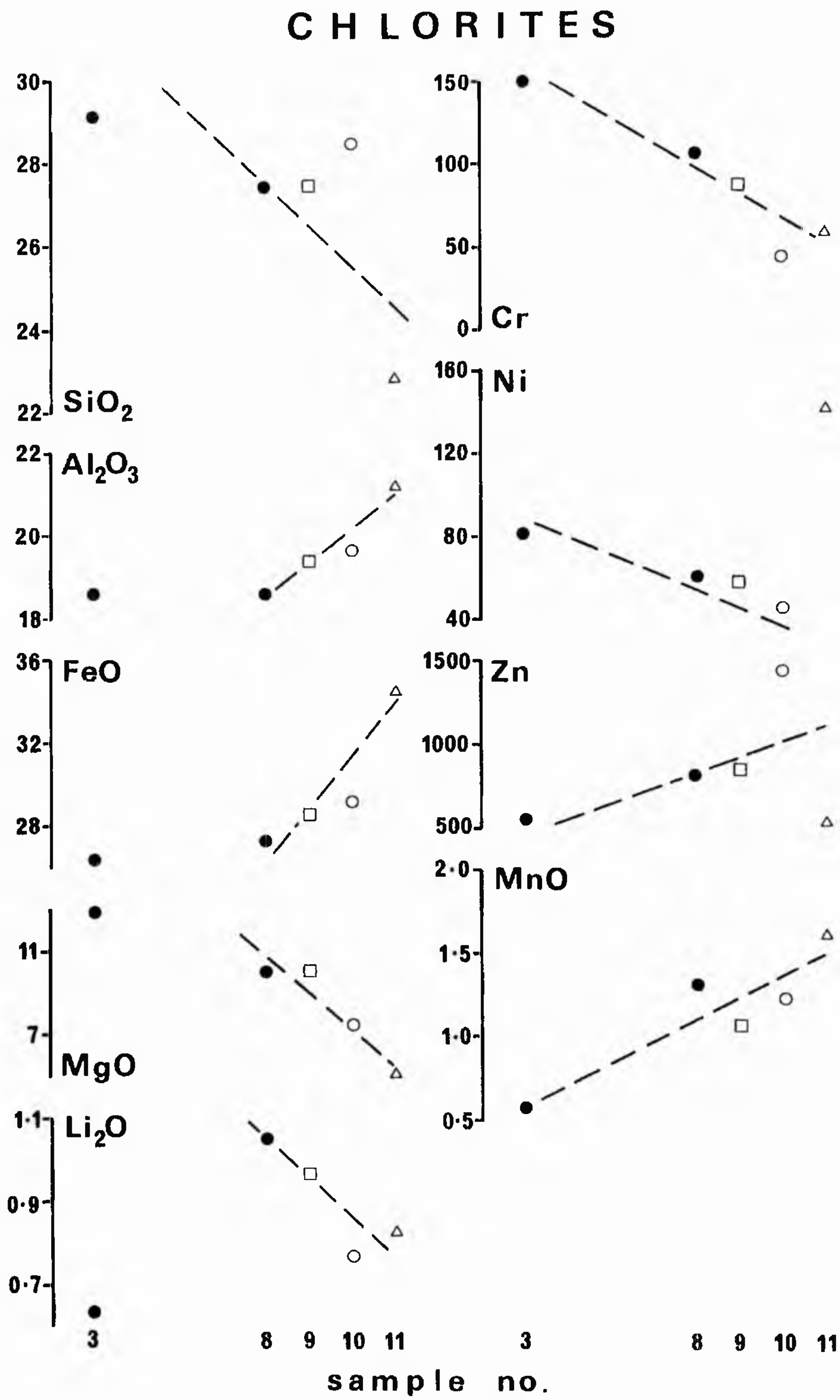


1-10 FLEET BIOTITES
CARSPHAIRN BIOTITES
I granite
II tonalite
III hornblende hybrid
A Mg biotite
B Fe biotite
C Li-Fe biotite
D Li siderophyllite
E protolithionite
F zinnwaldite
Al_{VI}, Li
40
80
Fe^{III}, Fe^{II}
70
Ti,Mn,Mg
1
2
3
4
5
6
7
8
10
I
II
III
Al_{VI},Li
F
E
D
C
B
A
FLEET
CARSPHAIRN
Fe^{III}, Fe^{II}
Ti,Mn,Mg


BIOTITES
SiO2
FeO
Al2O3
MgO
K2O
Li2O
MnO
Zn
Cr
Ni
Be
TiO2
sample no.



Al VI, Li
40
Fe''', Fe''
80
Ti,Mn,Mg
70
P
10
9
8
3
11
Si
Fe'' + Fe'''
Fe'' + Fe''' + Mg
Pseudothuringite
Corundophillite
Daphnite
Ripidolite
Sheridanite
Brunsvigite
Pycnochlorite
Clinochlore
Diabanite
Penninite
Talc-chlorite
Thuringite
Chamosite
Delessite


CHLORITES
SiO2
Al2O3
FeO
MgO
Li2O
Cr
Ni
Zn
MnO
sample no.

FIGURES 47 - 74.

FIG. 47. Ternary diagram of octahedral Al_{vi}, Li - Fe^{3+}, Fe^{2+} - Ti^{4+}, Mn^{2+}, Mg^{2+} in muscovites. Symbols from Figure 40. Inset ternary diagram of octahedral Li^{+}-Al^{3+}, Ti^{4+}, Fe^{3+} - Fe^{2+}, Mn^{2+}, Mg^{2+} in biotites and muscovites, after Foster (1960).

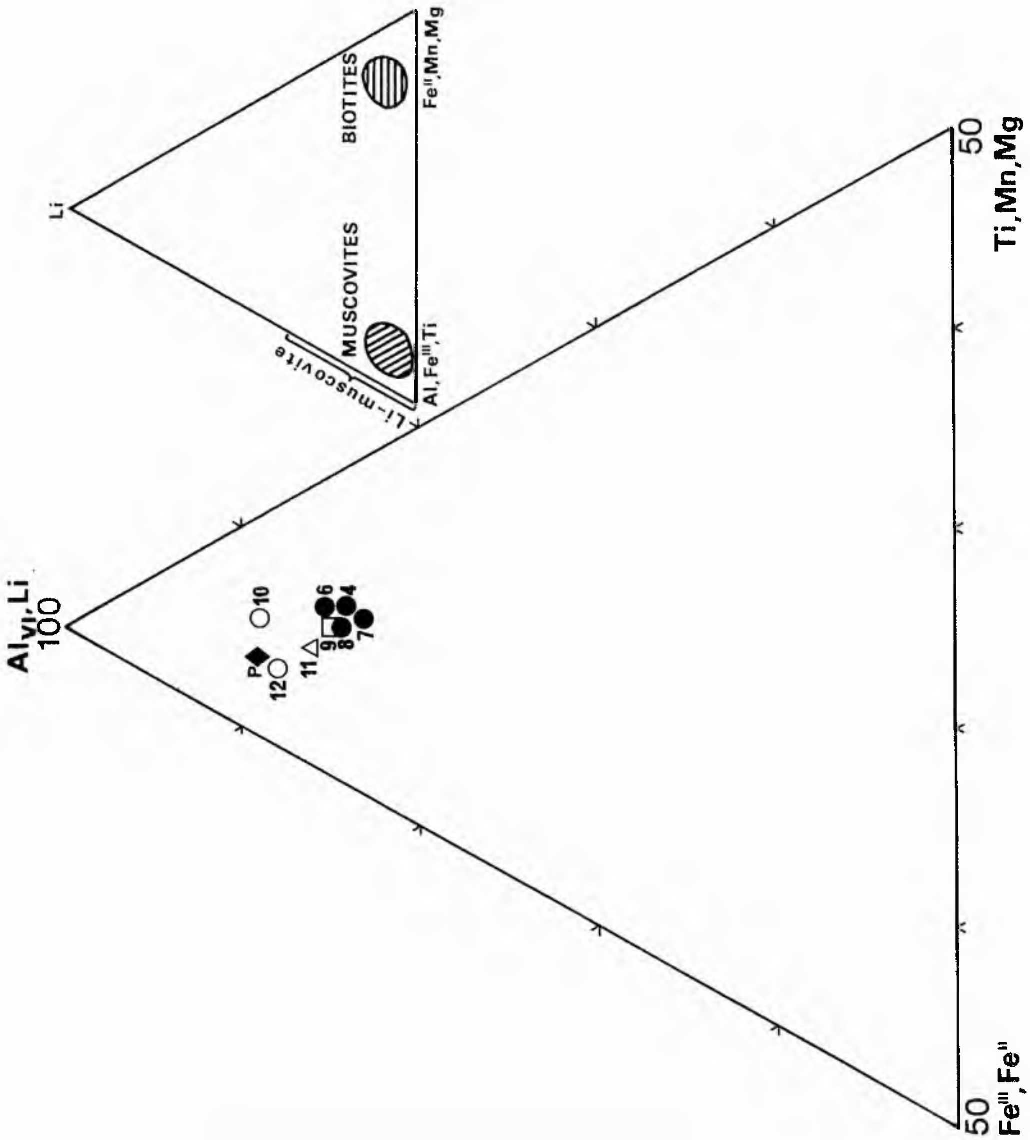
FIG. 48. Chemical variations in muscovite from samples 4-12, (Fig. 40).

FIG. 49. Chemical variation in feldspar/quartz fractions from samples 1-12 (Fig. 40).

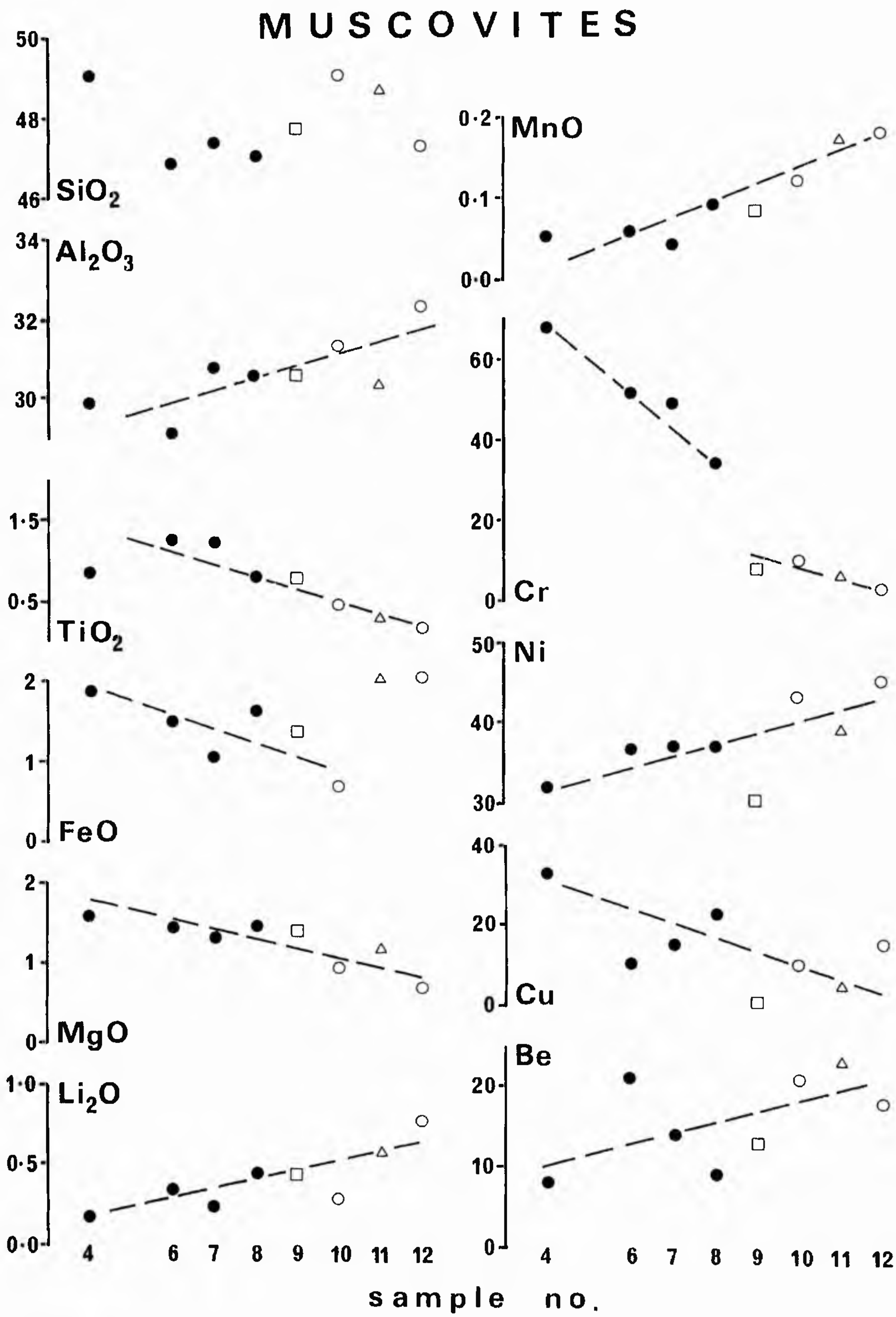
FIG. 50. Top, ternary diagram of K_2O-Na_2O-CaO in feldspar/quartz fractions of samples 1-12, P = pegmatite 73/517F. Bottom, ternary diagram of Rb-Li (x 10)-Sr in feldspar/quartz fractions.

FIGS. 51, 52, 54-56, 58-61, 63-68 and 70-74. Contour (top), trend surface (middle) and residual maps (bottom) of chemical and mesonormative data. Order of trend surfaces, fits and correlation coefficients are provided in table 13. On the contour map of Differentiation Index areas of less than 87.6 are indicated by diagonal lines, and areas above 92.1 are stippled.
Scale bar = 5 km; arrow points to north.

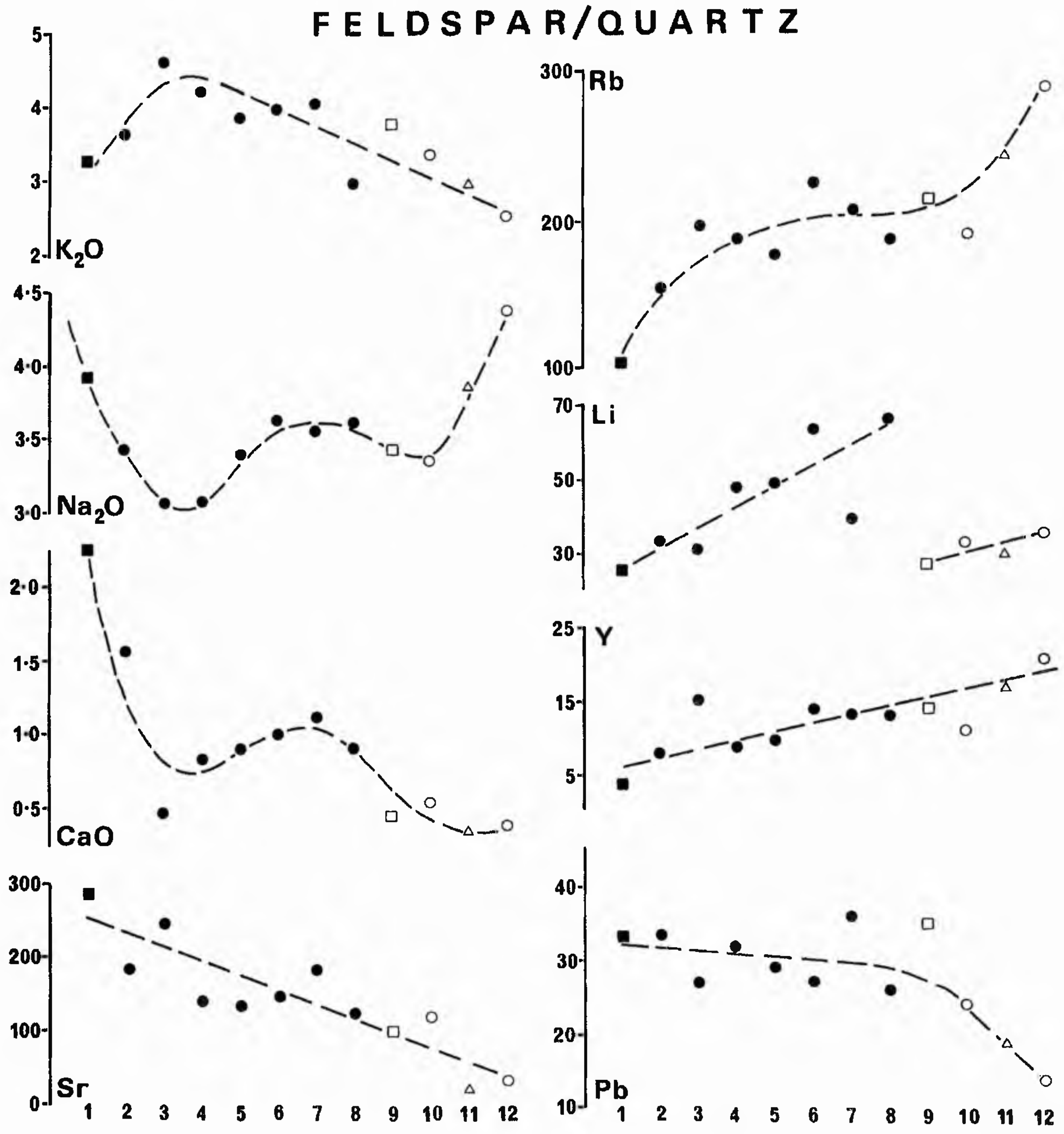
FIGS. 53, 57, 62 and 69. Contour maps of chemical and normative data from which non significant trend surfaces were obtained.
Scale bar = 5 km; arrow points to north.

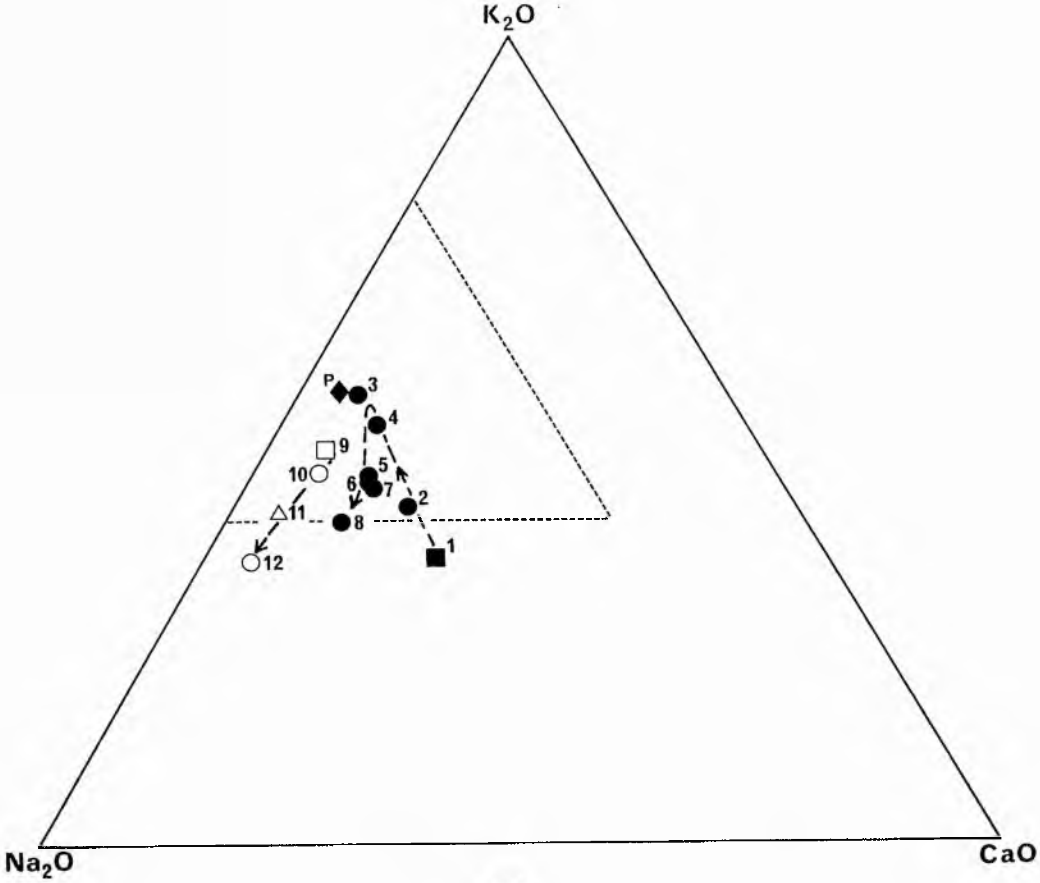


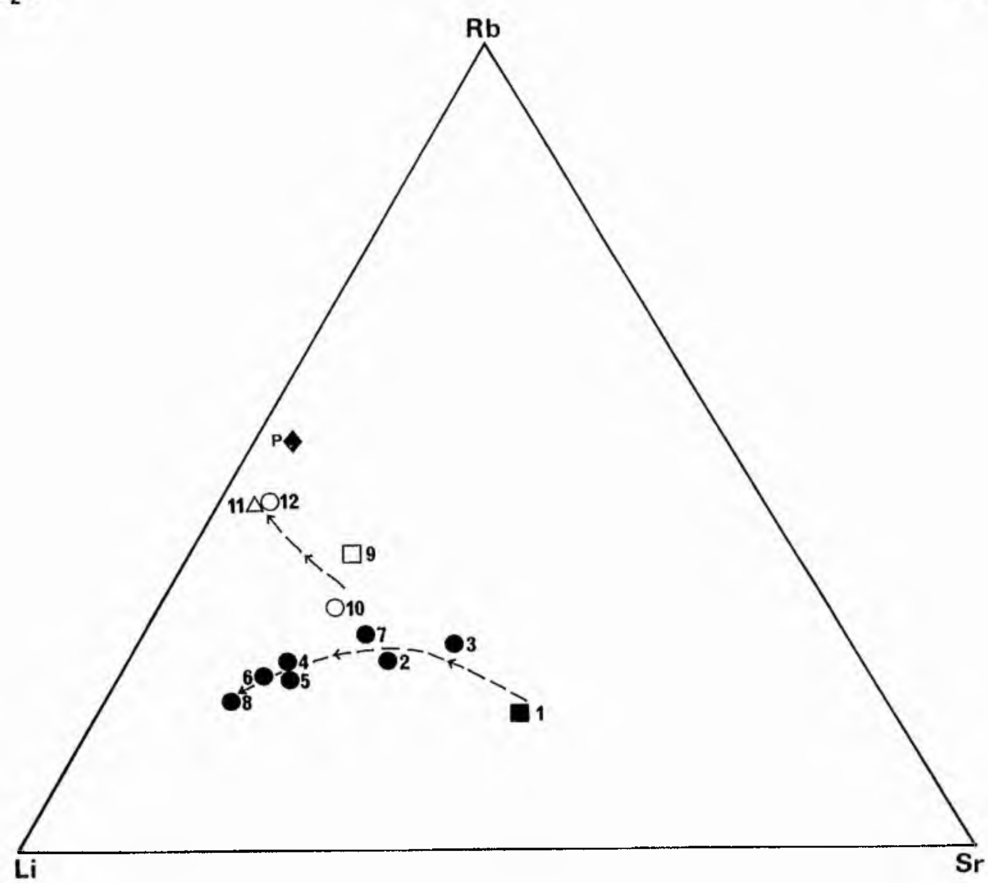
Al VI, Li
100
Fe''', Fe''
50
Ti, Mn, Mg
50
Li
MUSCOVITES
BIOTITES
Li-muscovite
Al, Fe''', Ti
Fe'', Mn, Mg
P
12
10
11
9
8
6
4
7

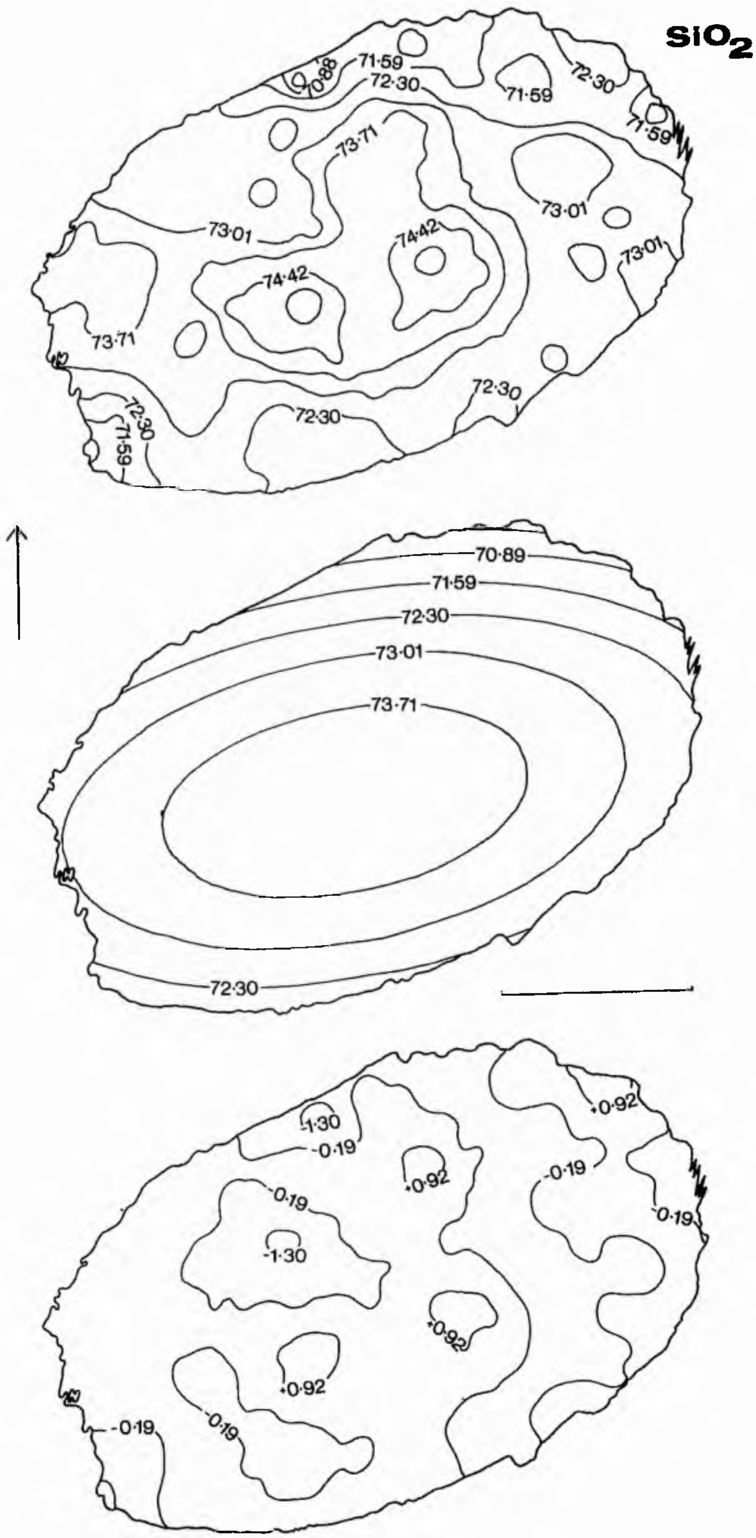


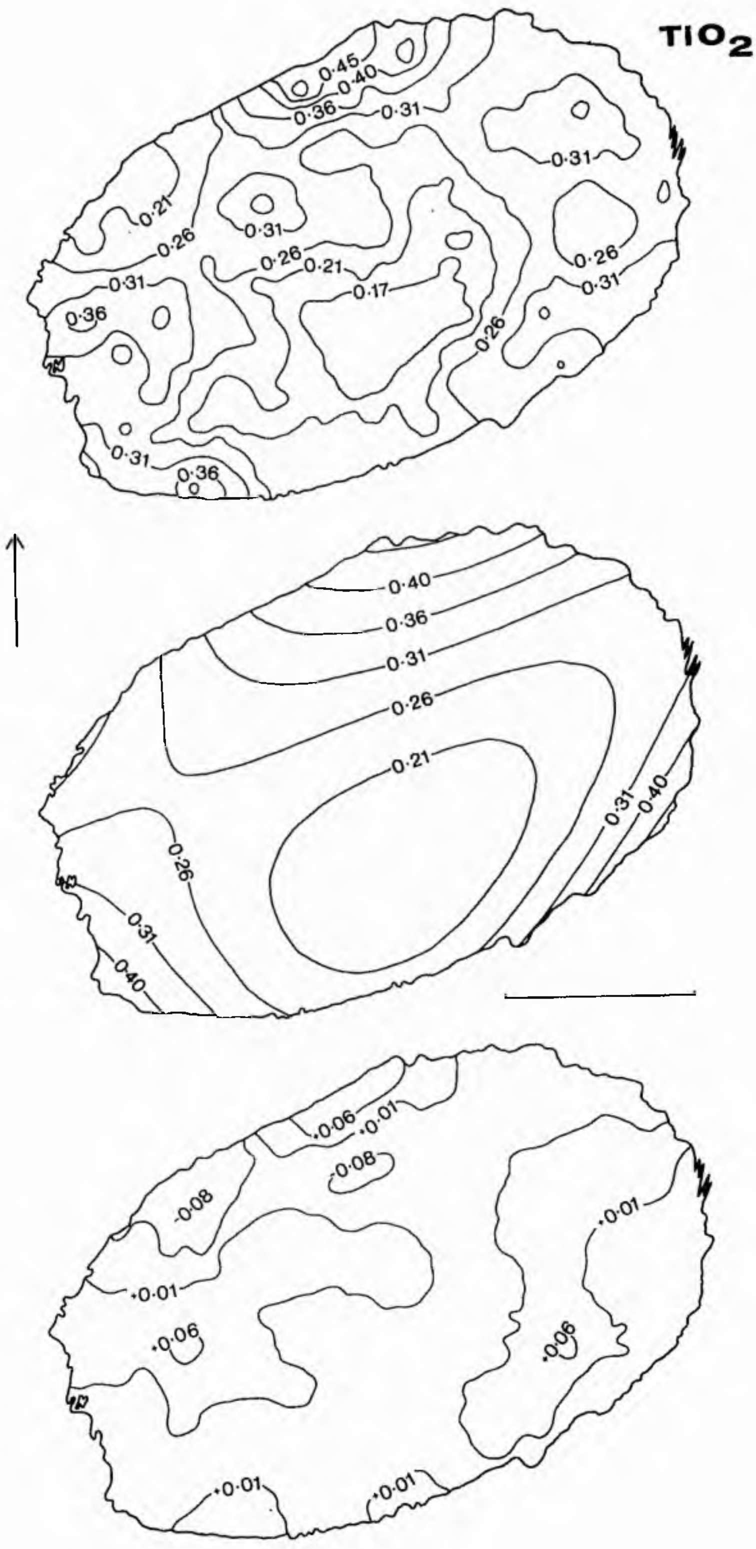
MUSCOVITES
SiO_2
Al_2O_3
TiO_2
FeO
MgO
Li_2O
MnO
Cr
Ni
Cu
Be
sample no.

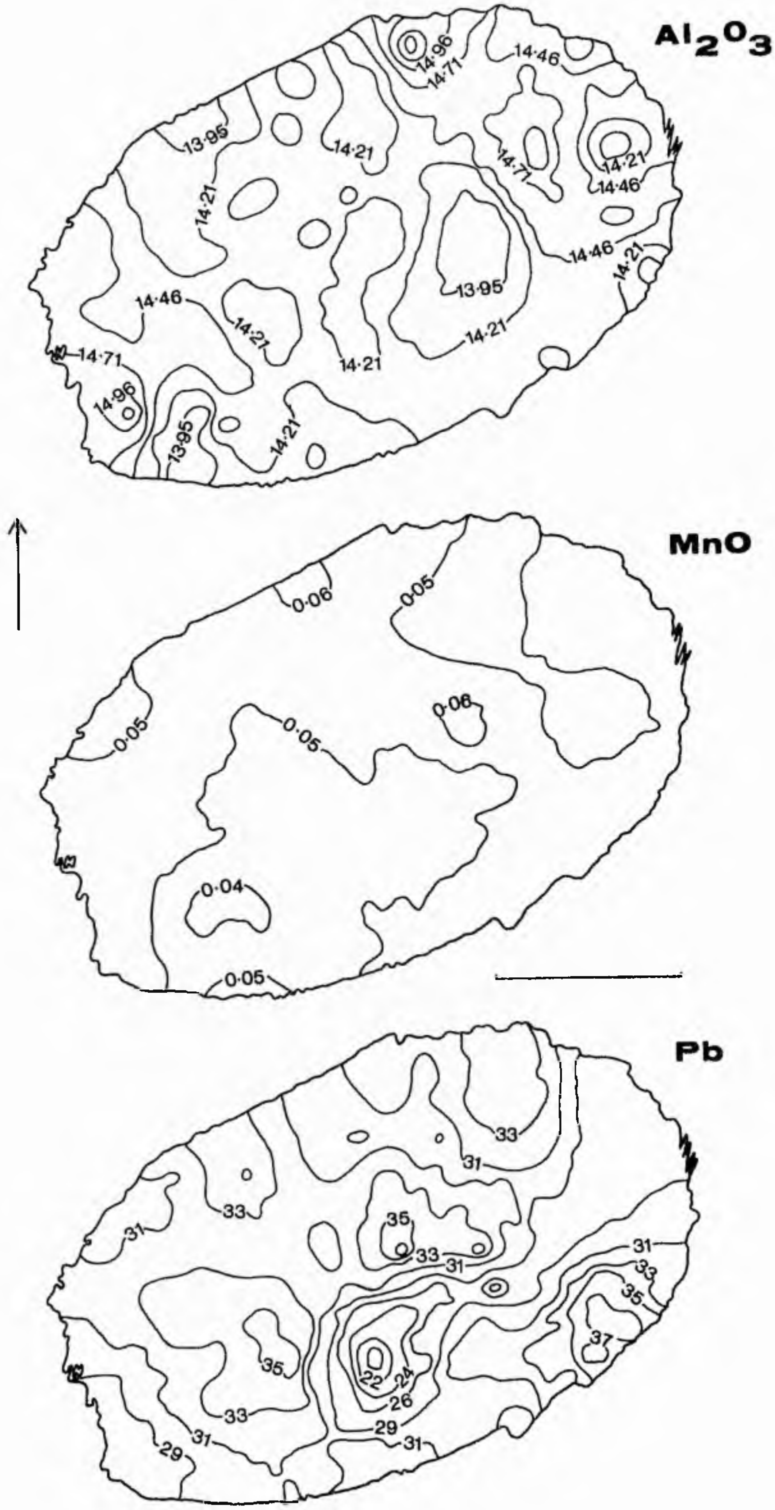

FELDSPAR/QUARTZ
K2O
Na2O
CaO
Sr
Rb
Li
Y
Pb
1 2 3 4 5 6 7 8 9 10 11 12

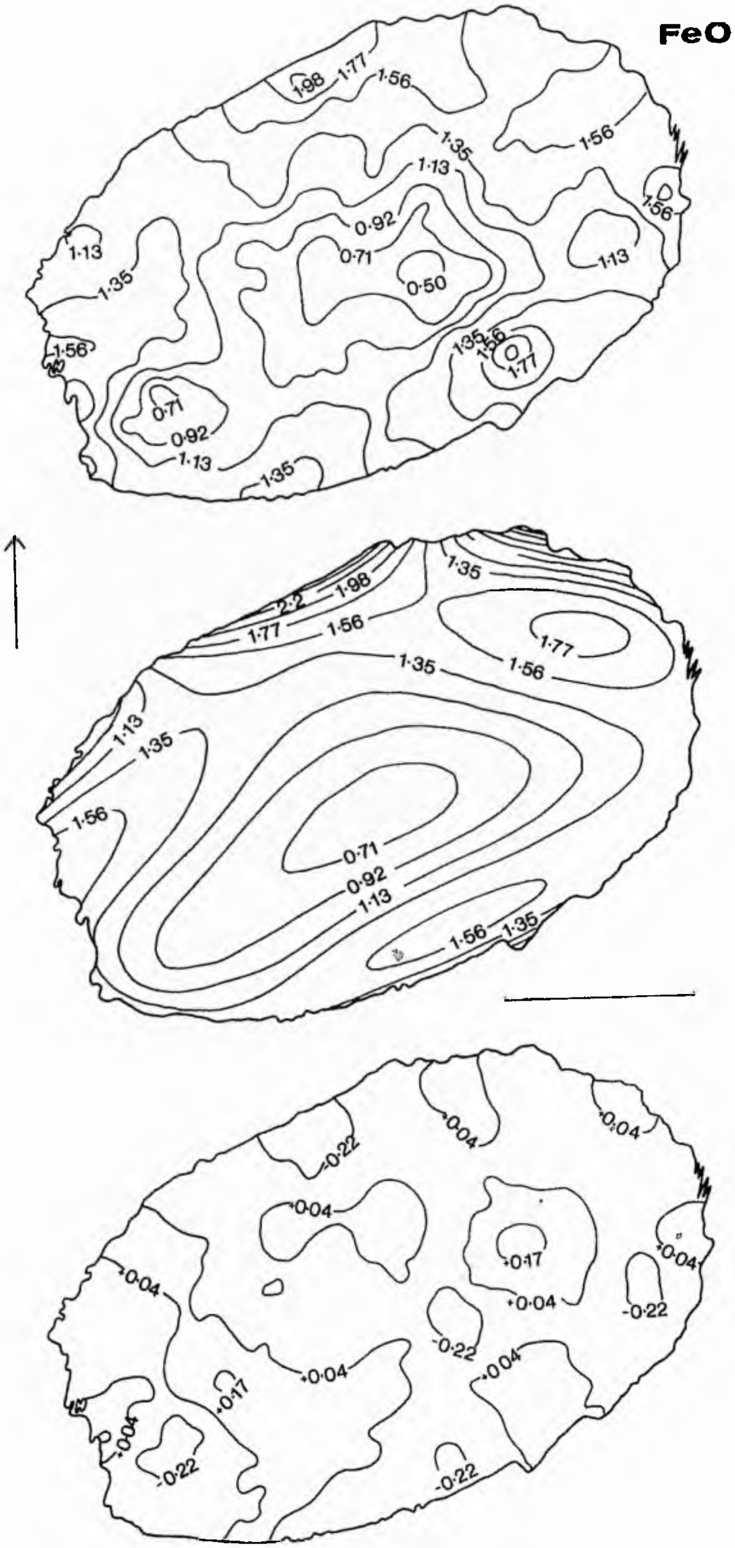

K2O
Na2O
CaO
P
1
2
3
4
5
6
7
8
9
10
11
12

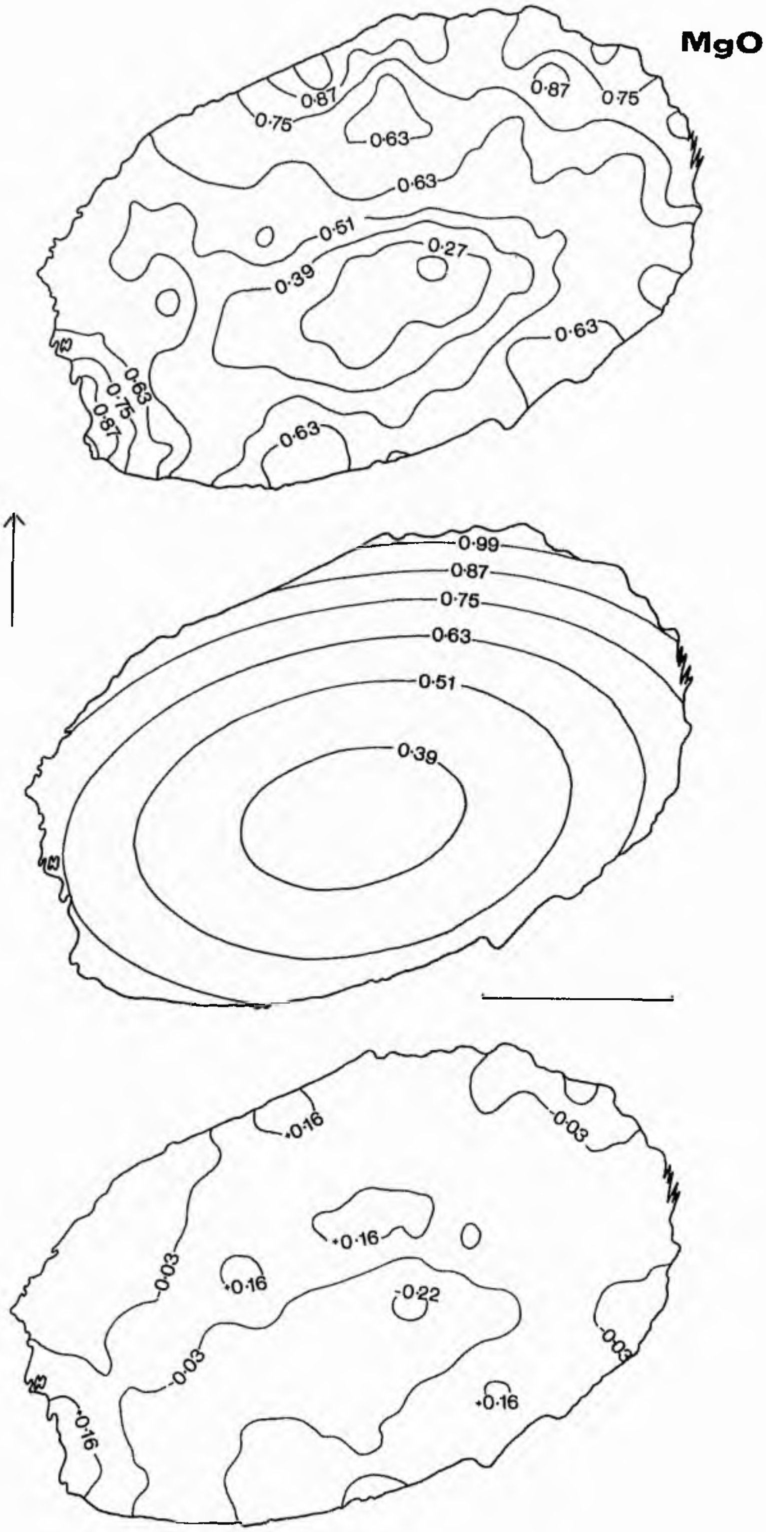

Rb
Li
Sr
P
1
2
3
4
5
6
7
8
9
10
11
12

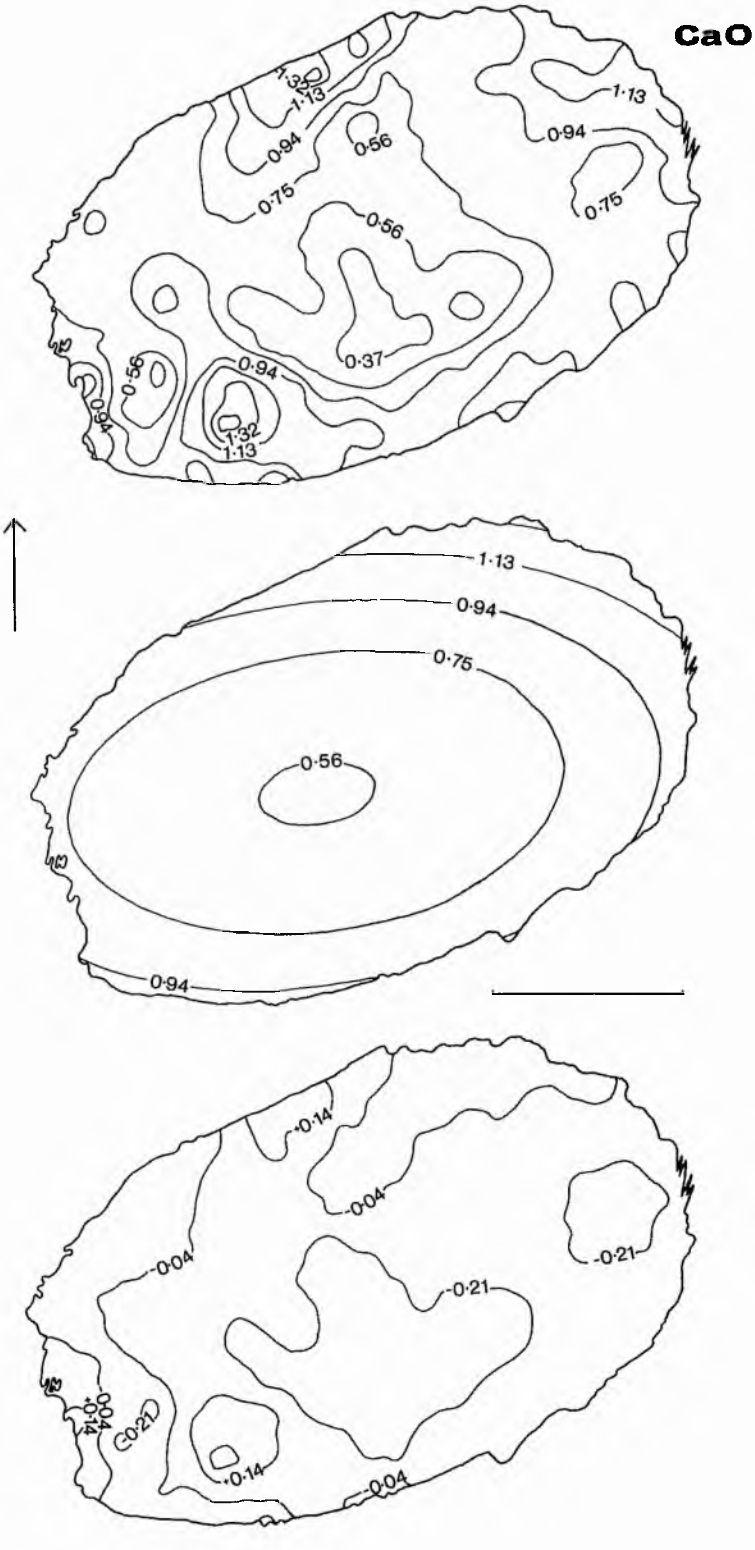

SiO2
71·59
70·88
72·30
71·59
72·30
71·59
73·71
73·01
73·01
74·42
74·42
73·01
73·71
72·30
72·30
72·30
71·59
70·89
71·59
72·30
73·01
73·71
72·30
+0·92
-1·30
-0·19
+0·92
-0·19
-0·19
-0·19
-1·30
+0·92
+0·92
-0·19
-0·19


TiO2
0·45
0·40
0·36
0·31
0·21
0·26
0·17
0·08
0·06
0·01


Al_2O_3
13·95
14·21
14·46
14·71
14·96
MnO
0·04
0·05
0·06
Pb
22
24
26
29
31
33
35
37

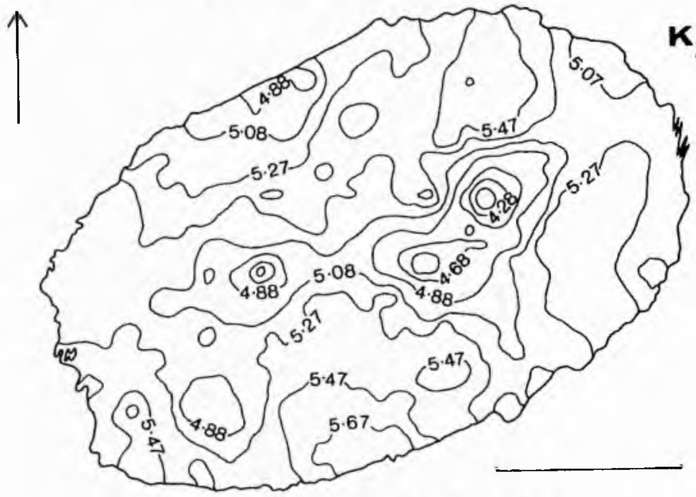

FeO
1·98
1·77
1·56
1·35
1·13
0·92
0·71
0·50
2·2
-0·22
+0·04
-0·04
+0·17
-0·17


MgO
0·87
0·75
0·63
0·51
0·39
0·27
0·99
+0·16
-0·03
-0·22

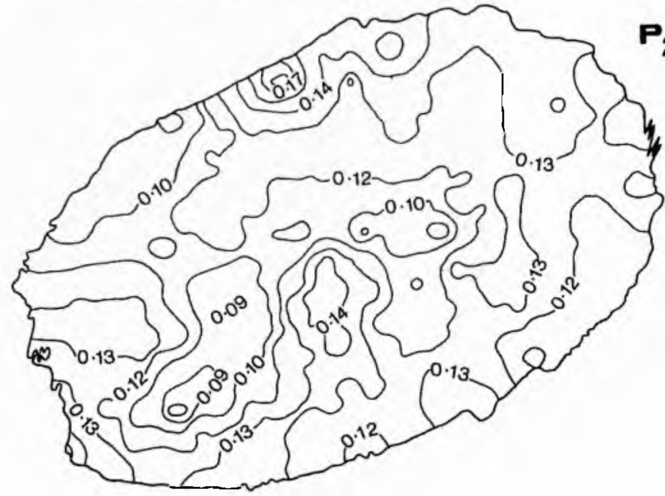

CaO
1·32
1·13
0·94
0·56
0·75
0·37
1·13
0·94
0·75
0·56
0·94
-0·14
-0·04
-0·21
+0·14
-0·04

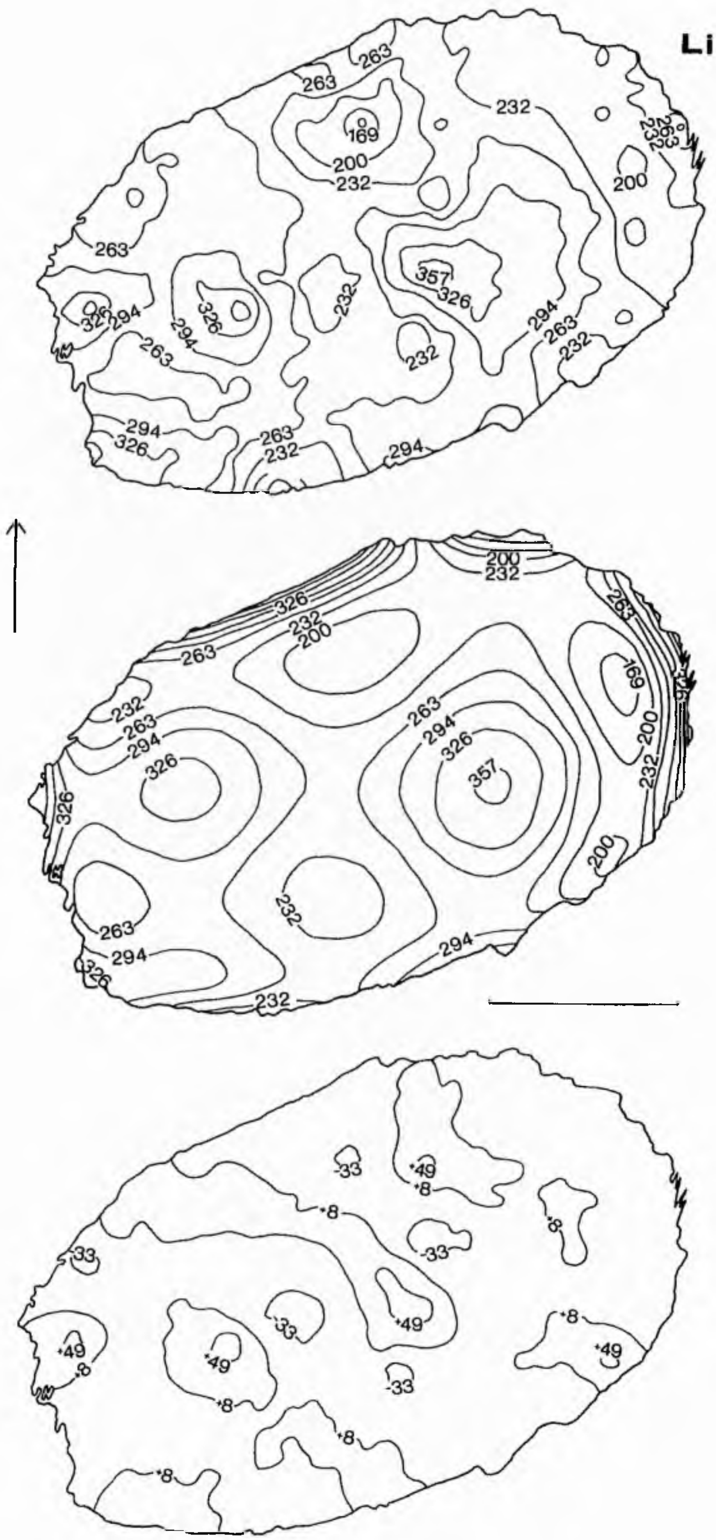
Na_2O

K_2O

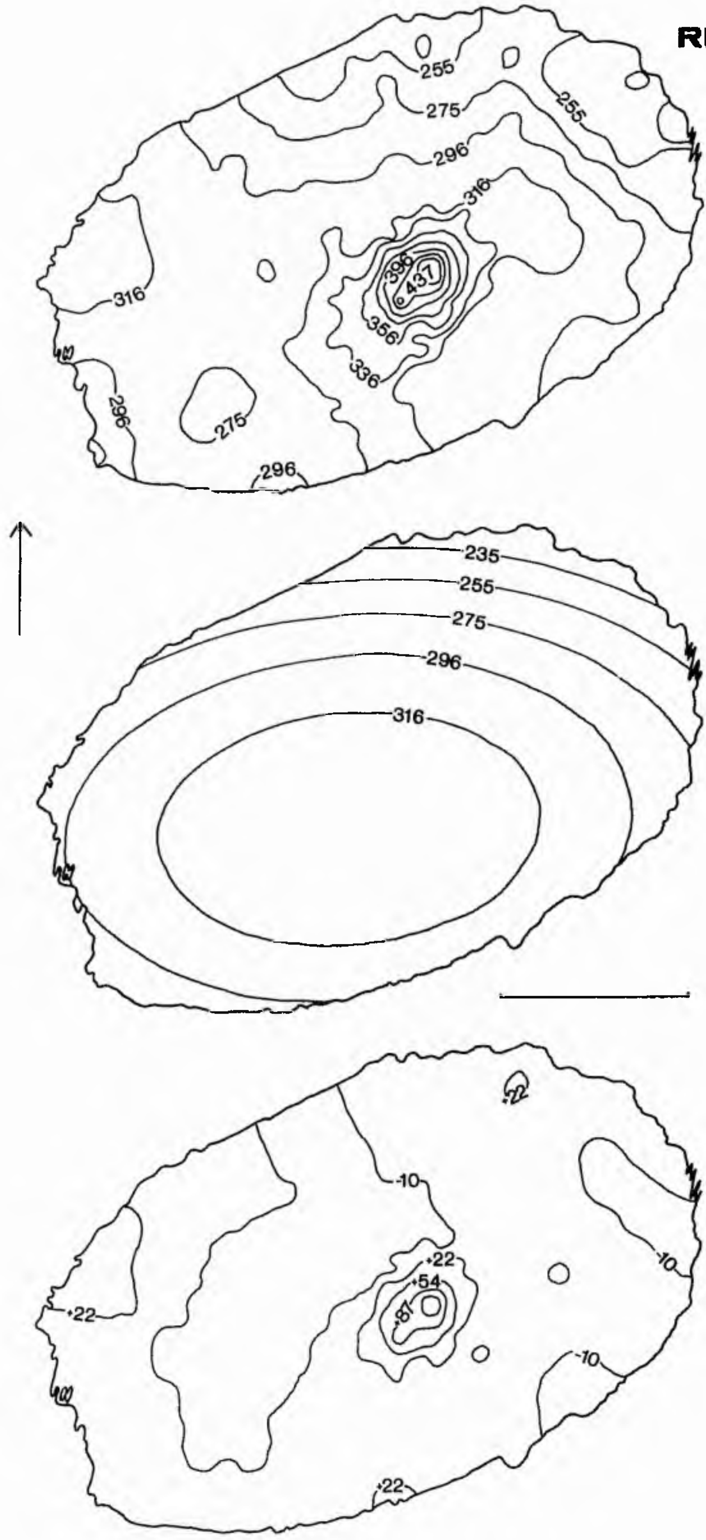


P_2O_5

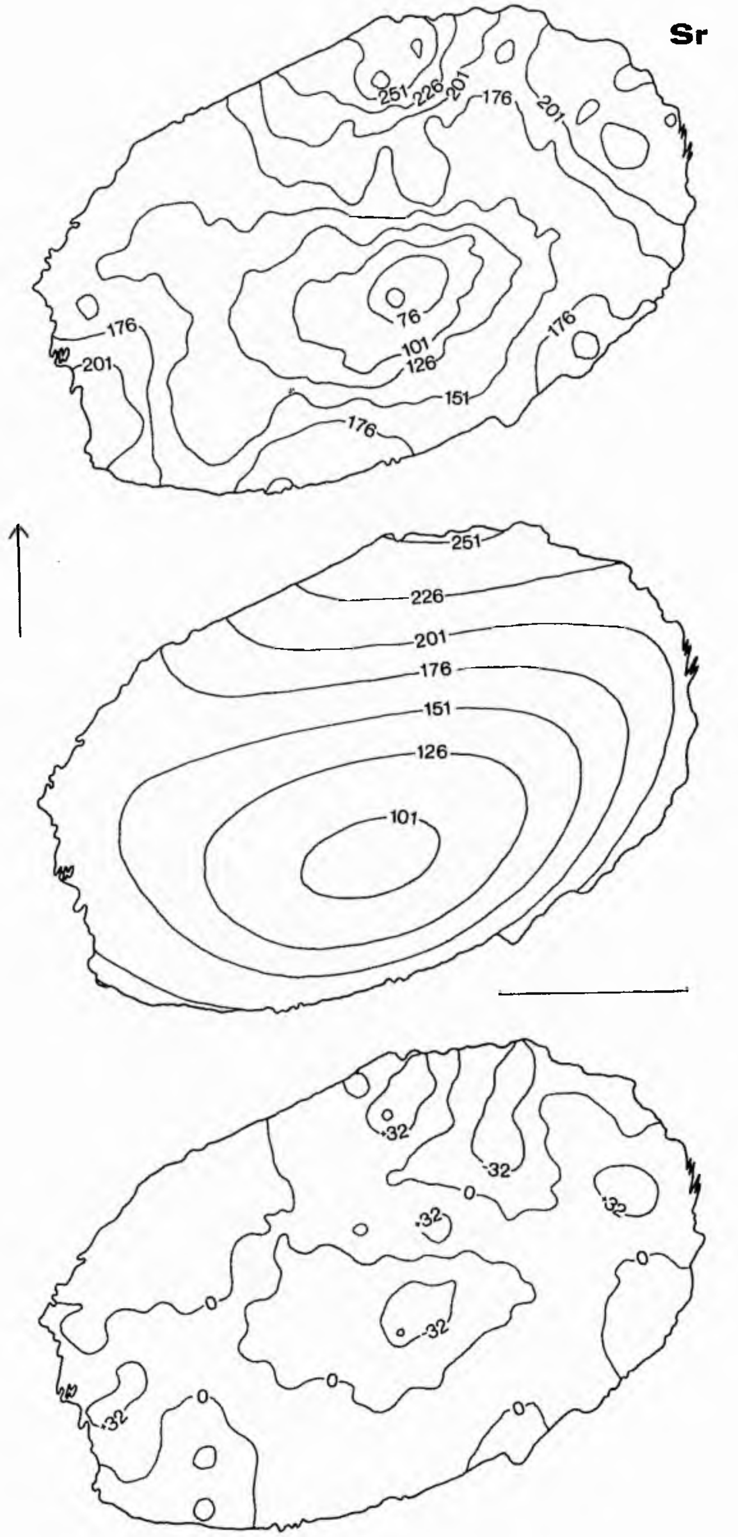


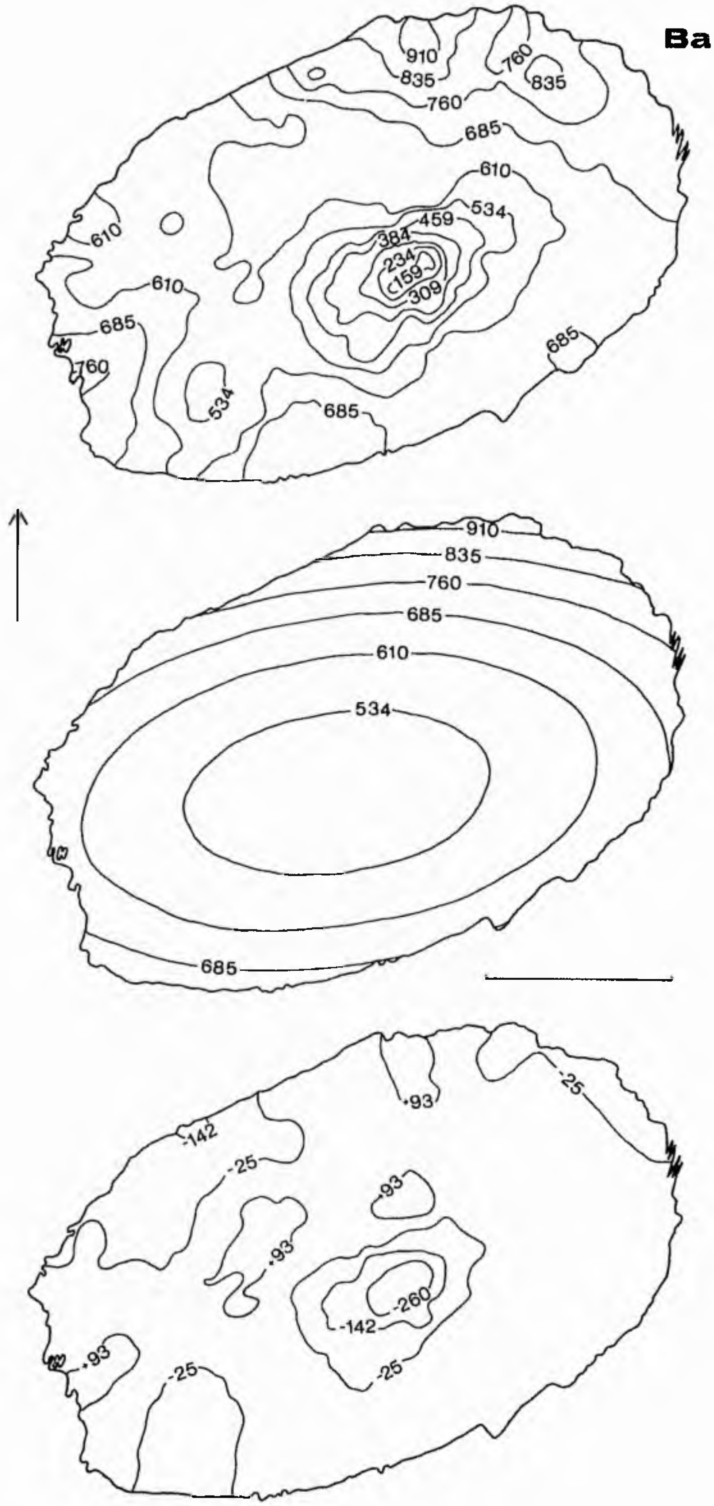

Li
263
232
169
200
357
326
294
-33
+49
+8

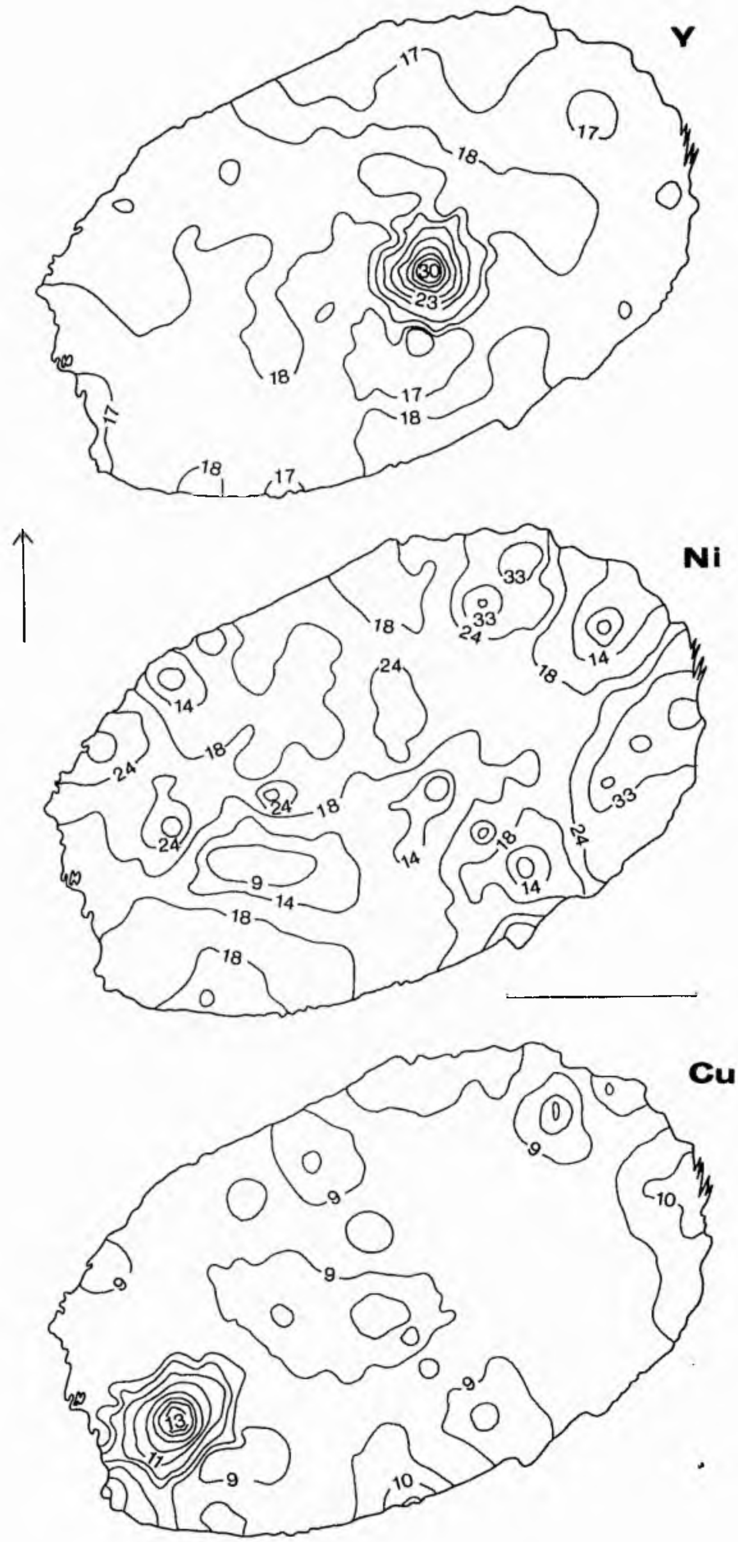
Rb

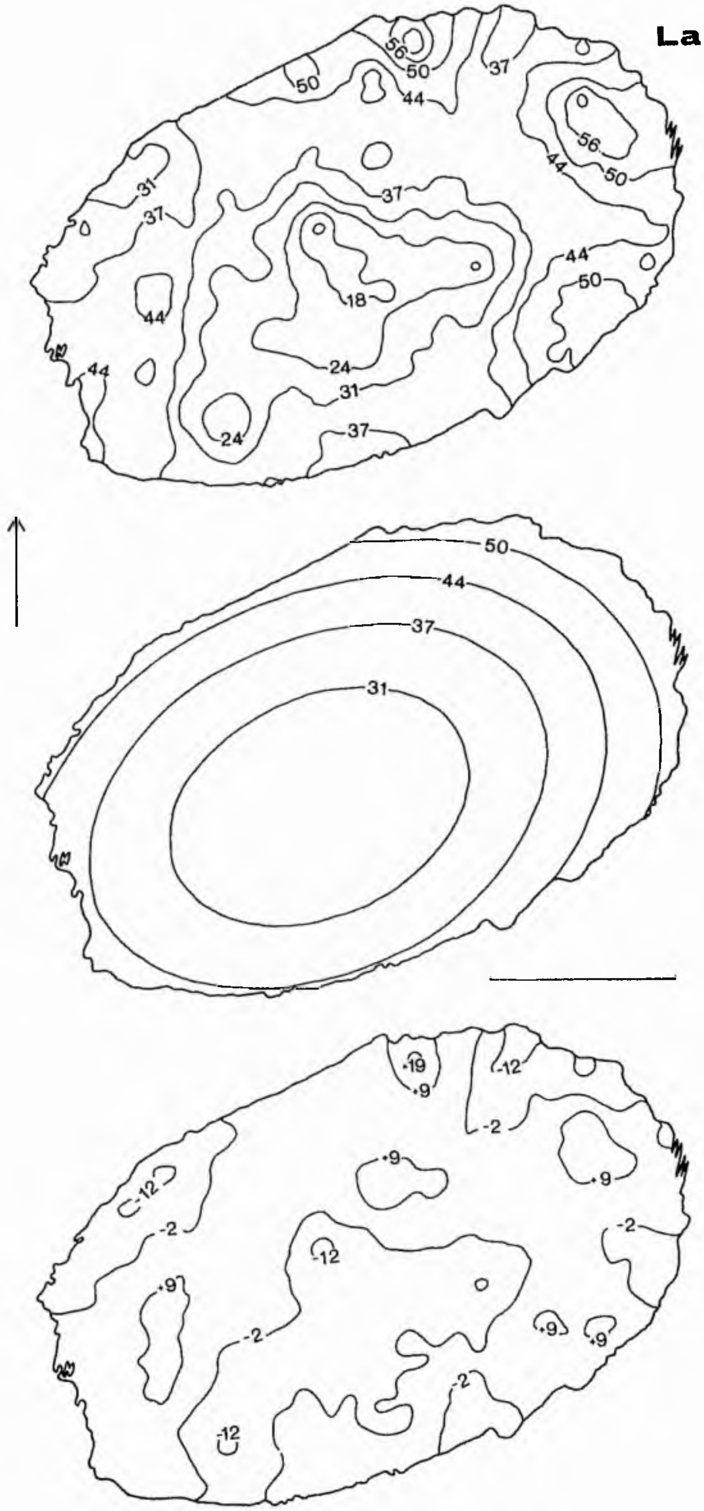


255
275
255
296
316
396
437
316
356
336
275
296
296
235
255
275
296
316
+22
-10
+22
+54
+87
-10
+22
-10
+22

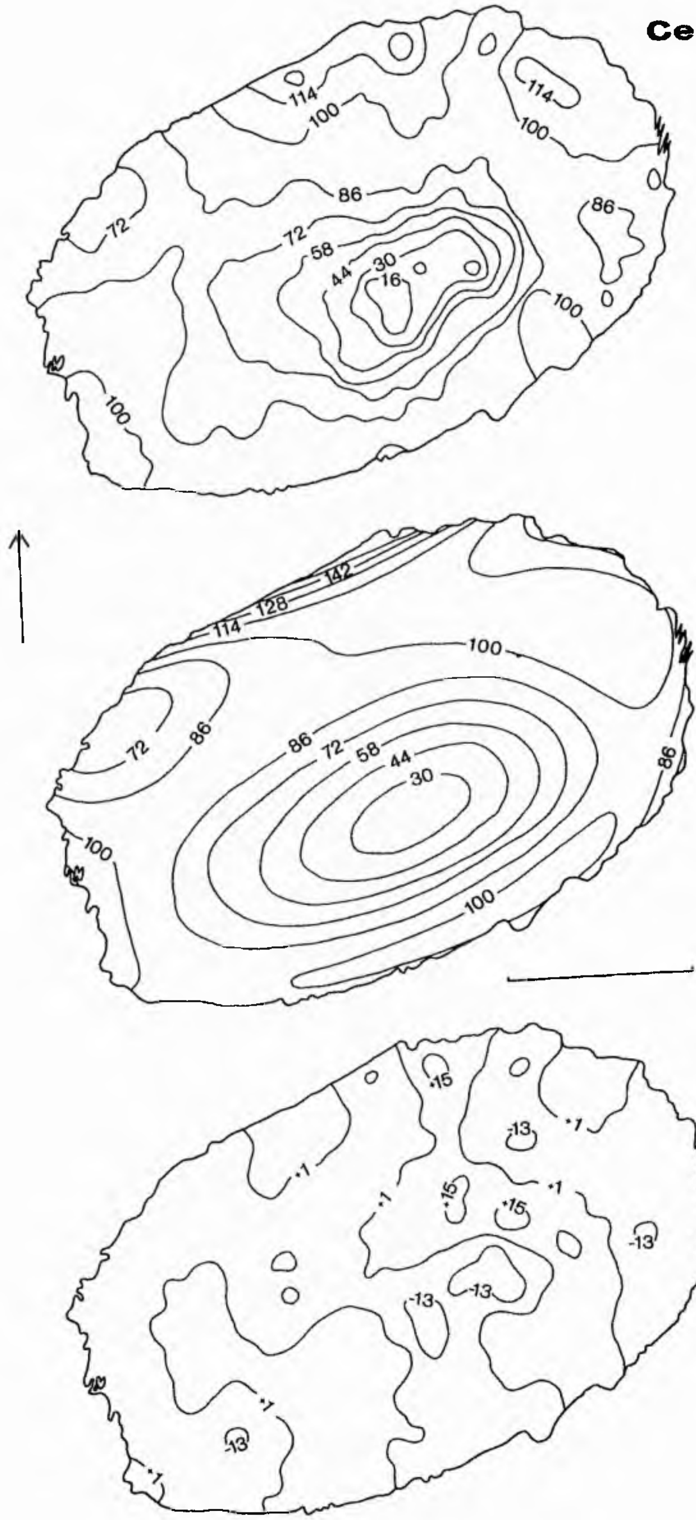

Sr
251
226
201
176
201
76
101
126
151
176
176
201
251
226
201
176
151
126
101
-32
-32
0
-32
-32
0
0
-32
0
0
-32
0
0

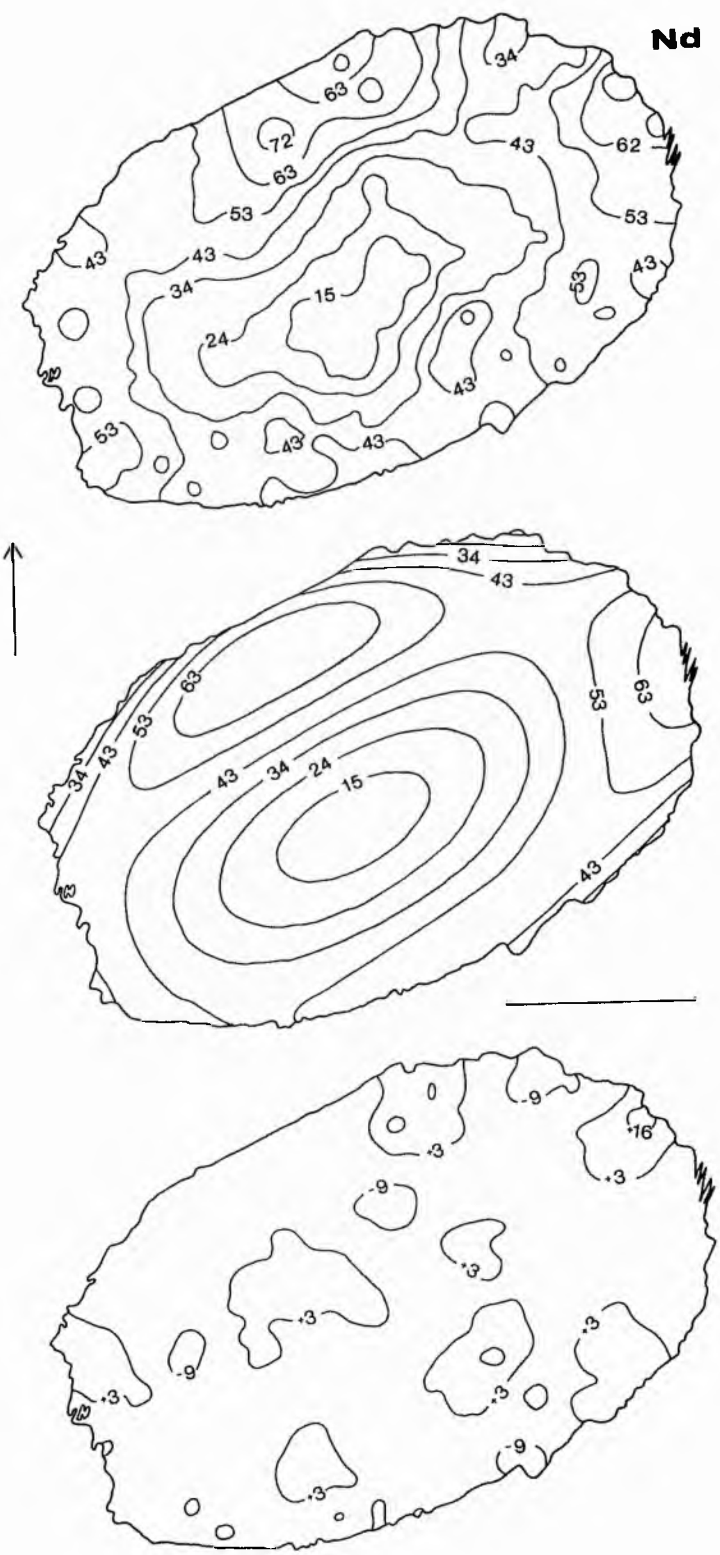

Ba
910
835
760
835
760
685
610
534
459
384
234
159
309
610
610
685
760
534
685
685
910
835
760
685
610
534
685
-25
-93
-142
-25
-93
-93
-260
-142
-25
-93
-25

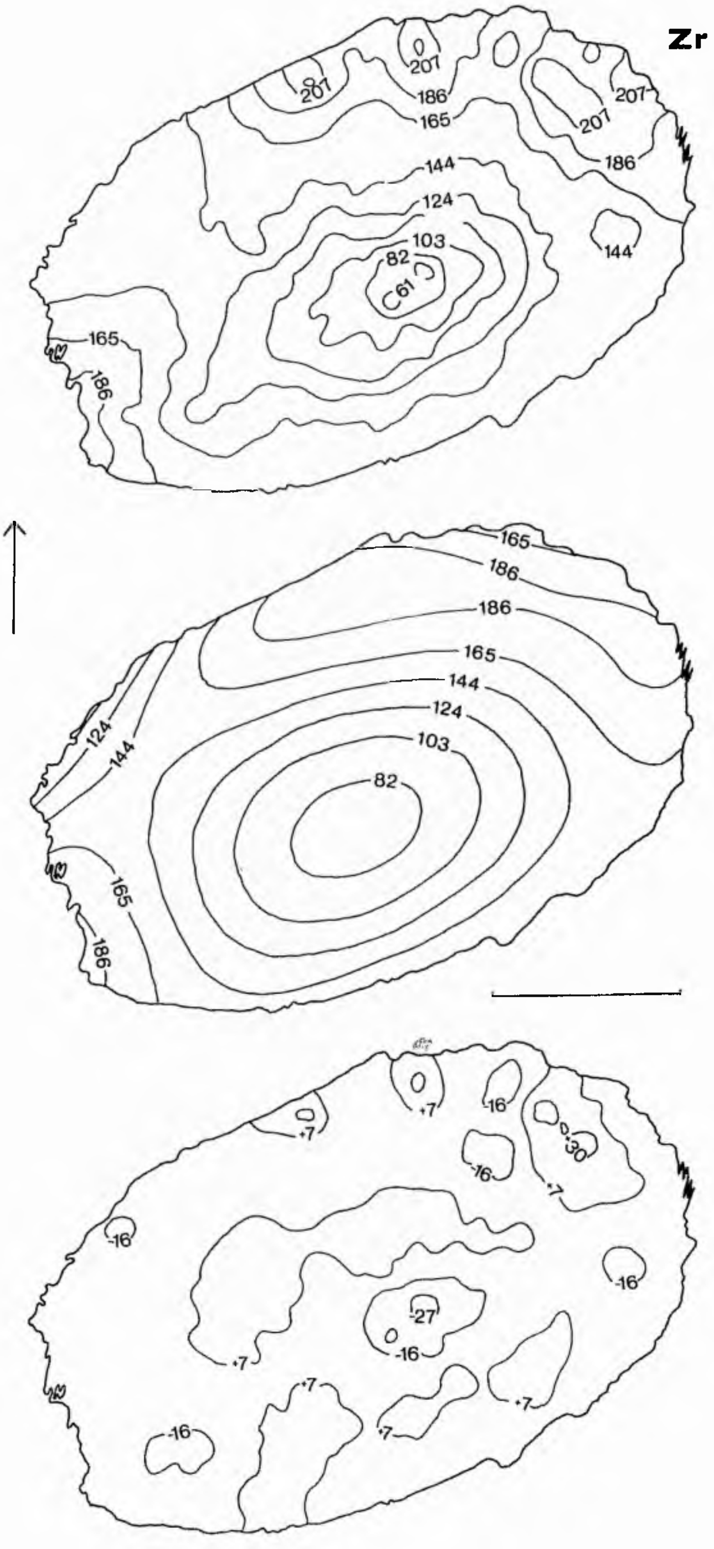

Y
17
17
18
30
23
18
17
18
17
18
17
Ni
33
33
18
24
14
24
14
18
18
24
24
24
18
33
24
24
14
9
14
18
14
18
18
Cu
9
9
10
9
9
13
11
9
9
10

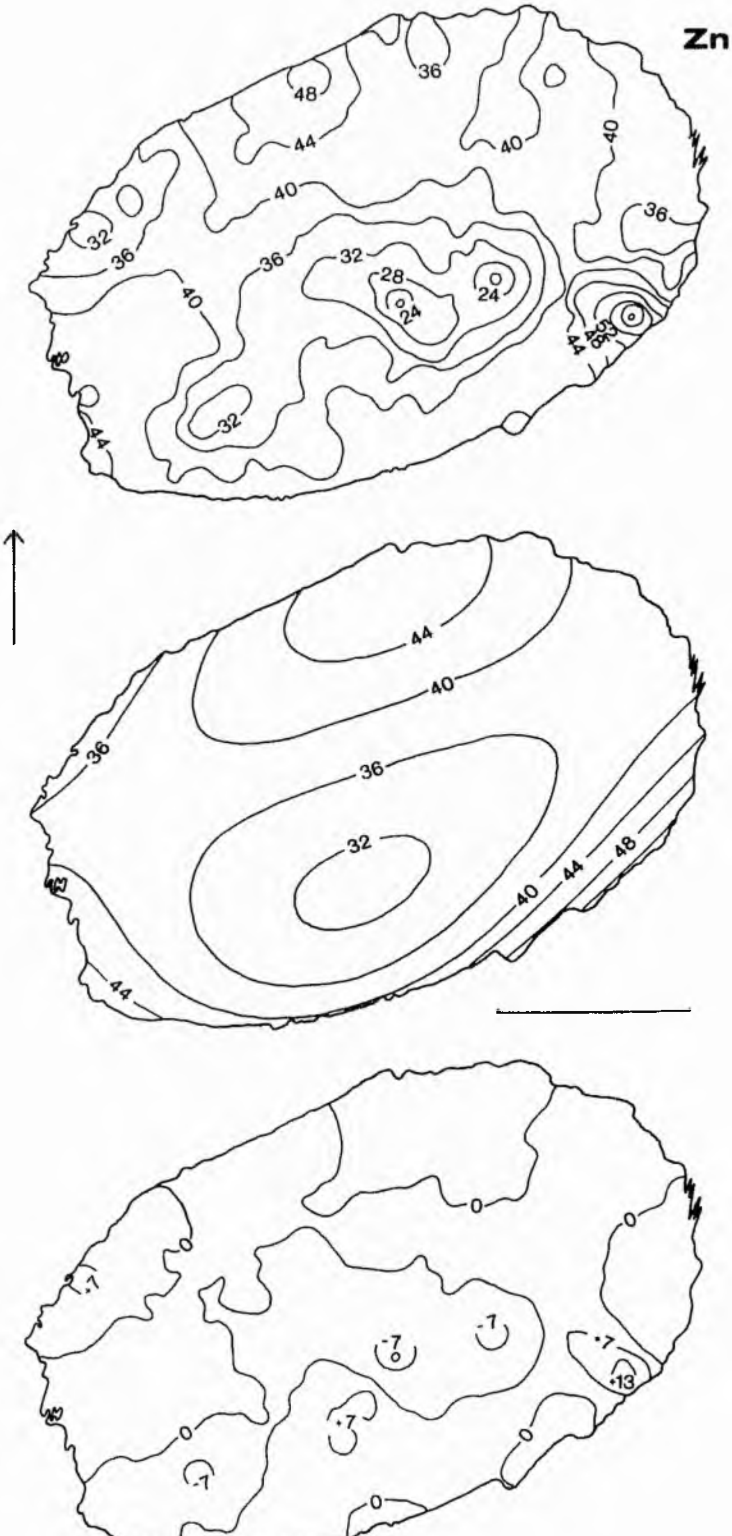


La
56
50
37
44
31
0
18
24
50
44
37
31
+19
+9
-12
-2
+9

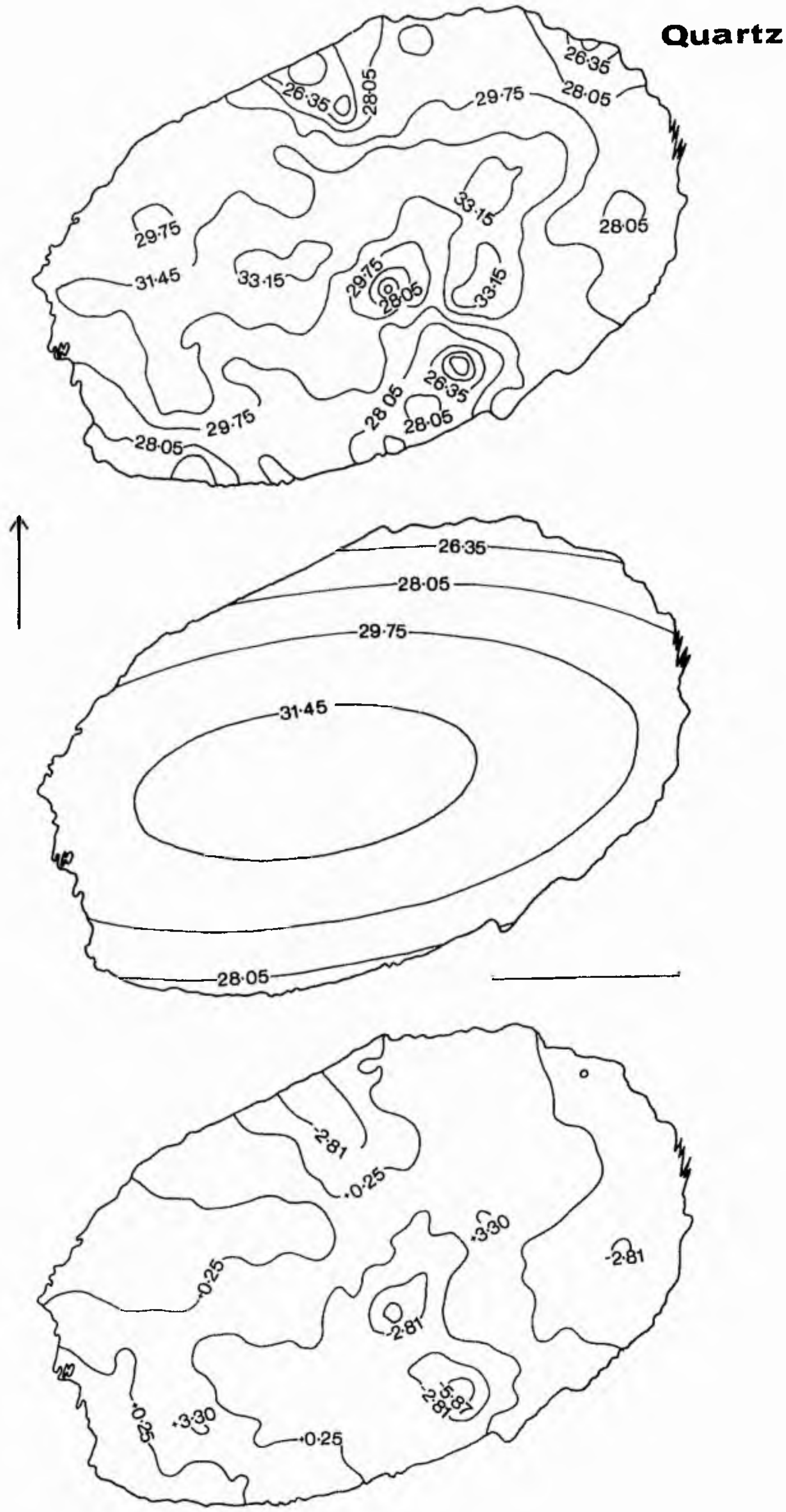

Ce
114
100
86
72
58
44
30
16
142
128
+15
+1
-13


Nd
72
63
53
43
34
24
15
62
43
34
24
15
53
63
-9
+16
+3
0

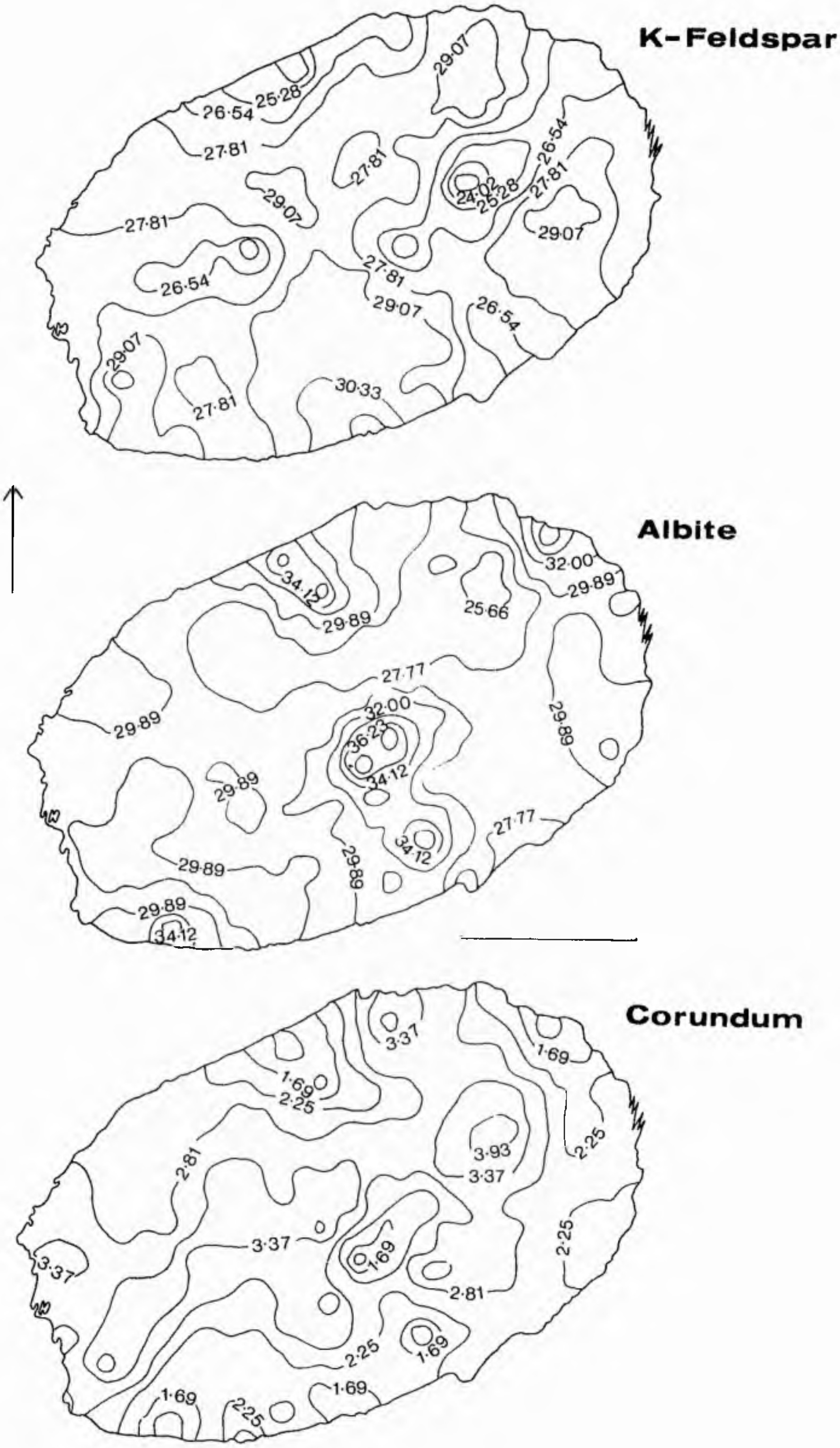

Zr
207
201
186
165
144
124
103
82
61
165
186
165
186
186
165
144
124
103
82
124
144
165
186
+7
-16
-30
-16
-27
-16
+7
+7
-7
-16



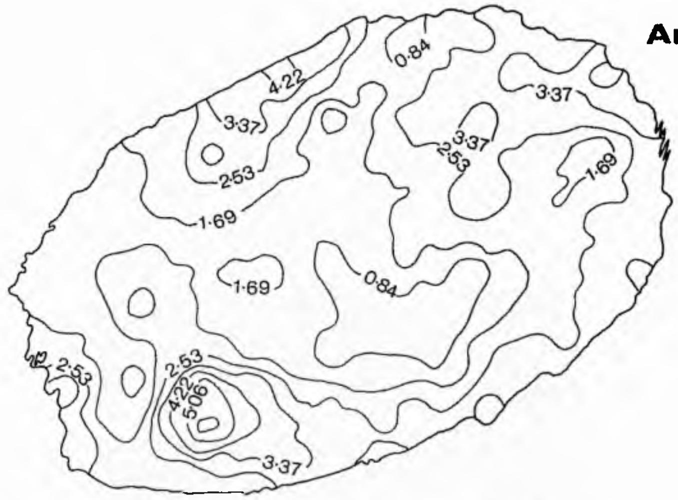
Zn
48
44
36
40
40
36
40
32
36
36
32
28
24
24
40
44
32
44
44
40
36
36
32
40
44
48
44
0
0
0
-7
-7
-7
-7
+7
+13
+7
0
-7
0
0



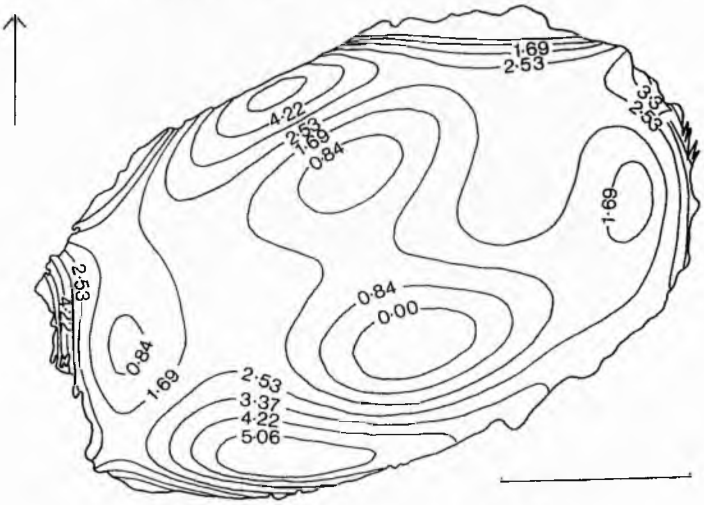
Quartz
26·35
28·05
26·35
29·75
28·05
29·75
33·15
28·05
31·45
33·15
29·75
28·05
33·15
26·35
28·05
28·05
29·75
28·05
26·35
28·05
29·75
31·45
28·05
2·81
0·25
3·30
2·81
0·25
2·81
5·87
2·81
0·25
3·30
0·25


K-Feldspar
29·07
25·28
26·54
27·81
24·02
30·33
Albite
32·00
29·89
34·12
25·66
27·77
36·23
Corundum
3·37
1·69
2·25
3·93
2·81

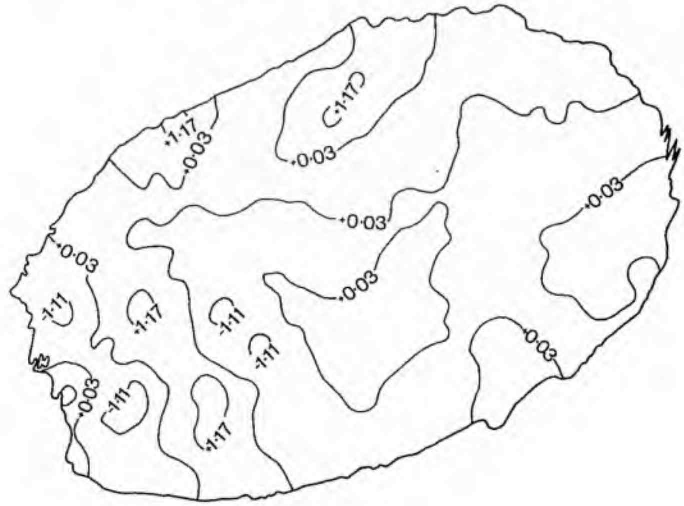
Anorthite



0·84
4·22
3·37
3·37
2·53
1·69
3·37
2·53
1·69
1·69
0·84
2·53
2·53
4·22
5·06
3·37

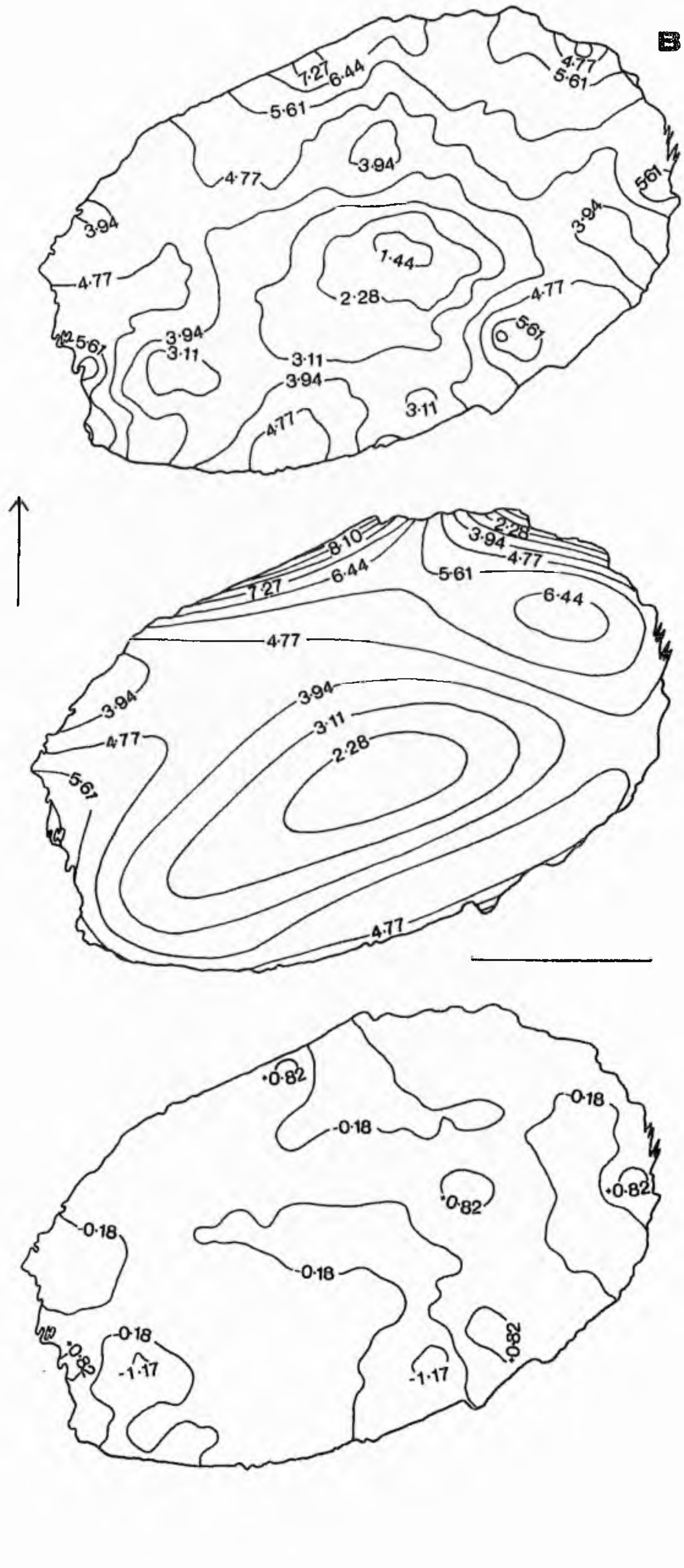


1·69
2·53
4·22
2·53
1·69
0·84
2·53
1·69
2·53
0·84
0·00
0·84
1·69
2·53
3·37
4·22
5·06

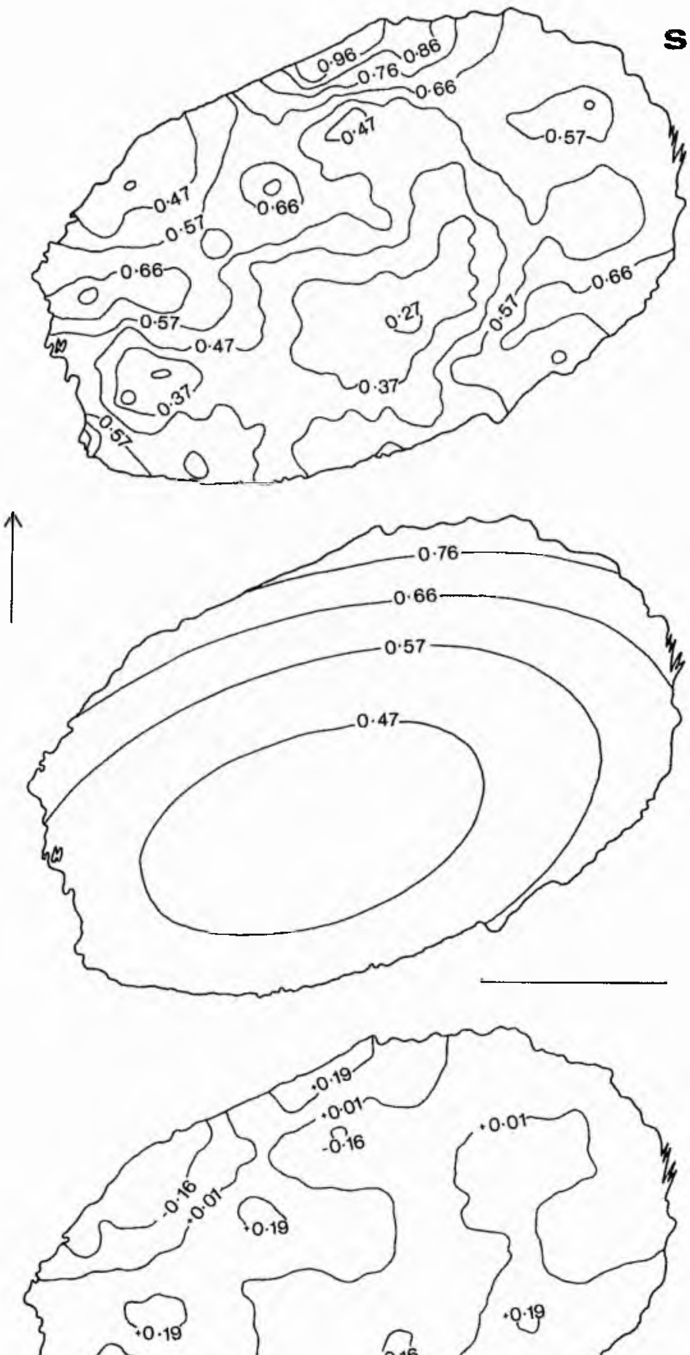


-1·17
+1·17
-0·03
+0·03
+0·03
-0·03
+0·03
+0·03
-1·11
+1·17
-1·11
-1·11
-0·03
-1·11
-1·17
-0·03

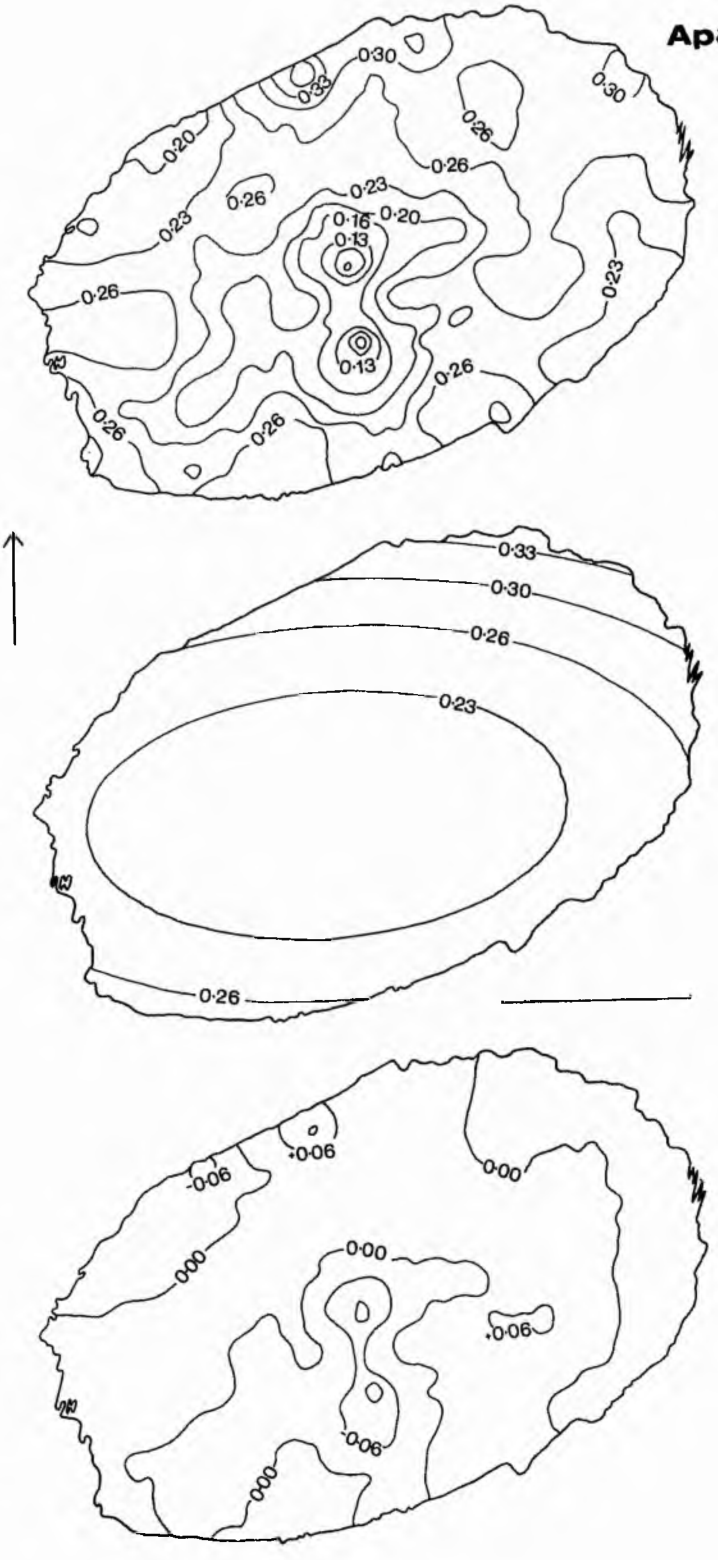
Biotite


7·27
6·44
4·77
5·61
5·61
3·94
4·77
5·61
3·94
3·94
1·44
4·77
2·28
4·77
5·61
5·61
3·94
3·11
3·11
3·94
3·11
4·77
8·10
2·28
3·94
4·77
6·44
5·61
7·27
6·44
4·77
3·94
3·94
3·11
4·77
2·28
5·61
4·77
0·82
0·18
0·18
0·82
0·82
0·18
0·18
0·18
0·82
0·82
-1·17
-1·17

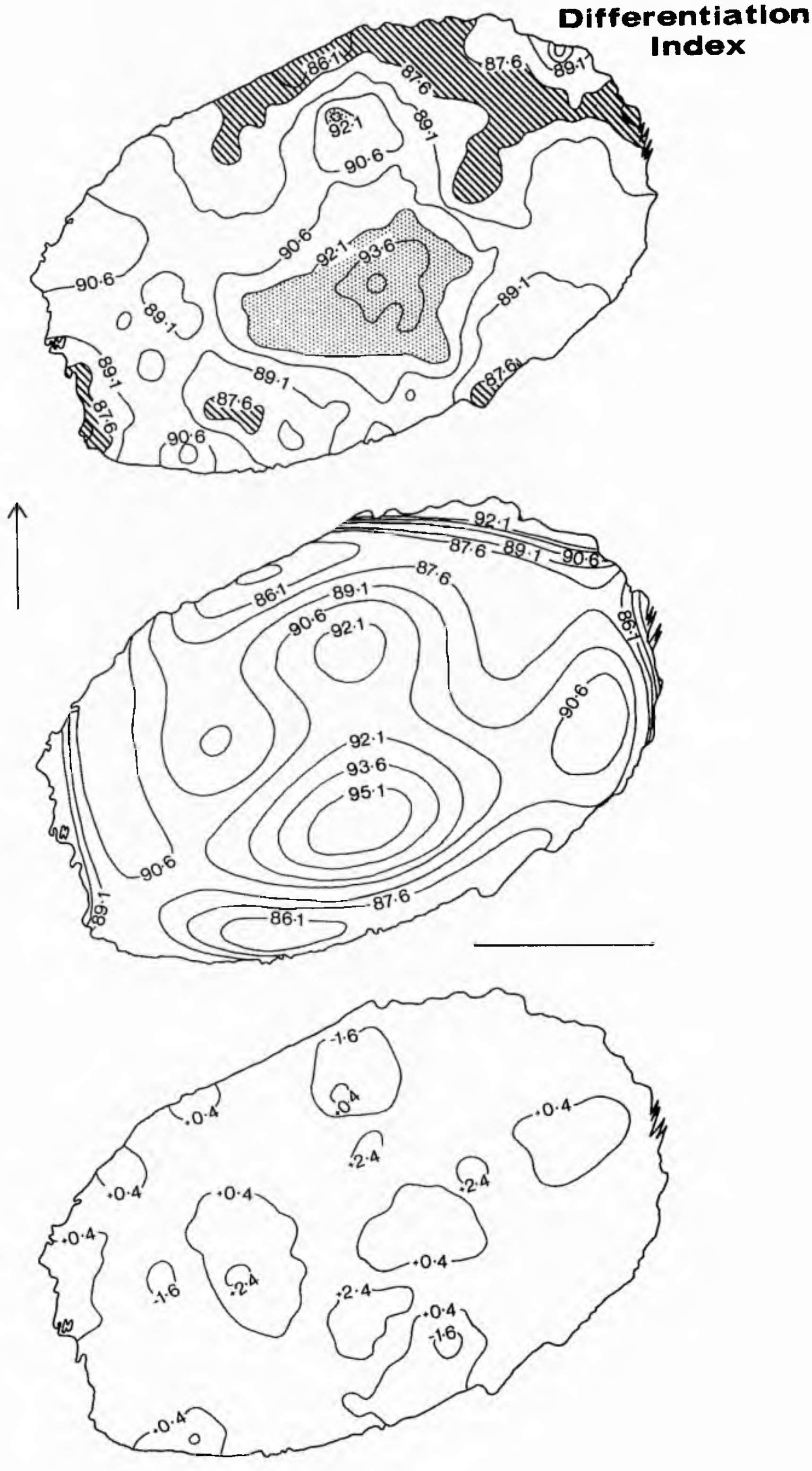
Sphene


0·96
0·86
0·76
0·66
0·47
0·57
0·47
0·66
0·57
0·66
0·57
0·47
0·27
0·57
0·66
0·37
0·37
0·57
0·76
0·66
0·57
0·47
+0·19
+0·01
-0·16
+0·01
-0·16
+0·01
+0·19
+0·19
+0·19
-0·16
-0·16
+0·01

Apatite



0·30
0·33
0·30
0·26
0·20
0·26
0·23
0·26
0·23
0·16
0·20
0·13
0·23
0·26
0·13
0·26
0·26
0·26
0·33
0·30
0·26
0·23
0·26
+0·06
-0·06
0·00
0·00
0·00
+0·06
-0·06
0·00


Differentiation Index
86·1
87·6
89·1
92·1
90·6
93·6
87·6
92·1
89·1
90·6
95·1
86·1
-1·6
+0·4
-2·4
+2·4

FIGURES 75 - 86.

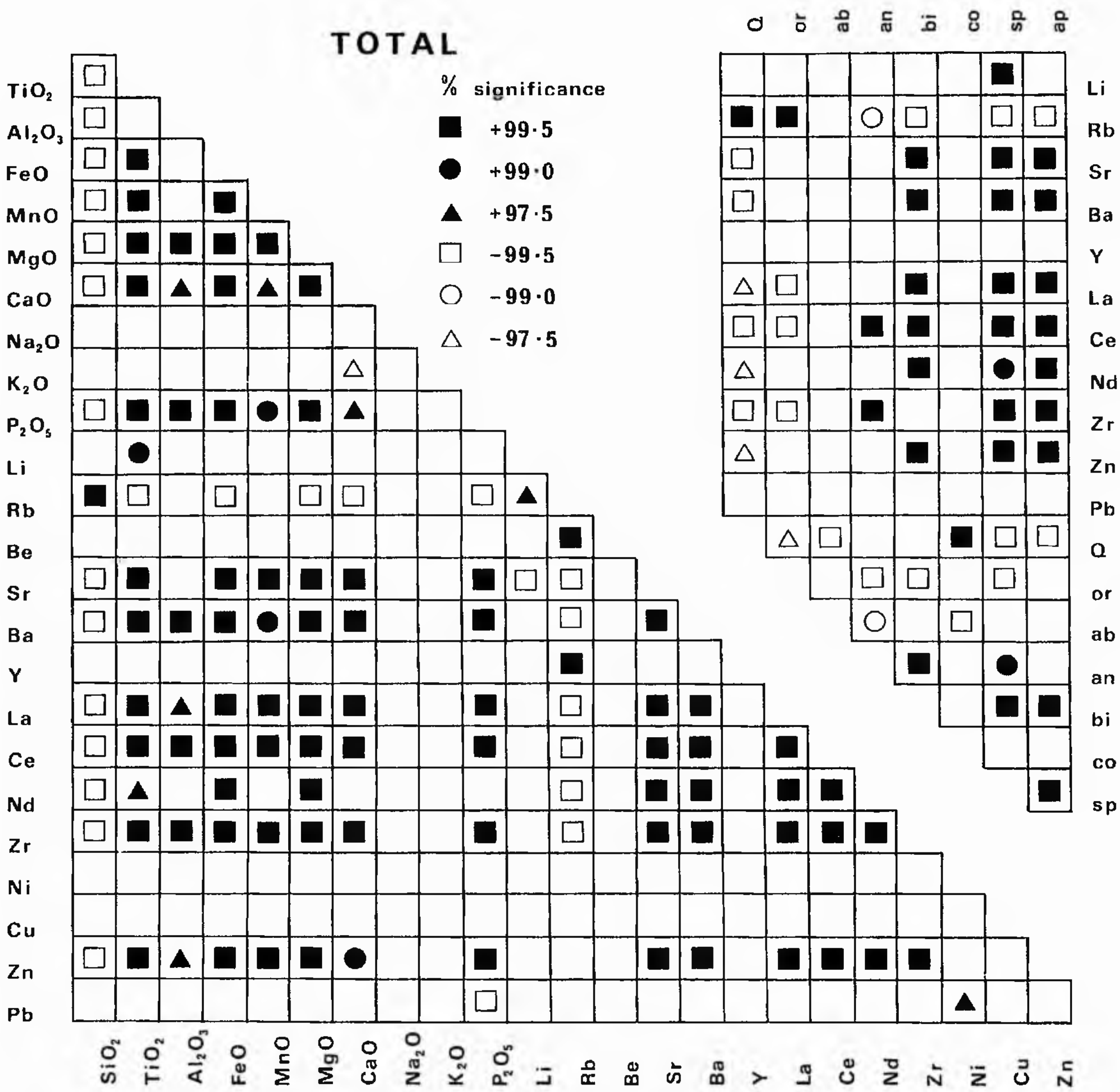
FIGS. 75-78. Matrices of correlations of chemical and mesonormative variables in the total data set and clusters 1-3 of the granite samples; + or - before the level of significance indicates a positive or negative correlation.

FIGS. 79-83. Scatter diagrams of chemical and mesonormative data. Regression lines of greater than 95.0% significance indicated on correlations greater than 97.5% significance. 1-3 = clusters, t = total, ⊡ = cluster 1, + = cluster 2, △ = cluster 3, ● = cluster 4, ORTHO = mesonormative orthoclase (Or), D.I. = Differentiation Index.

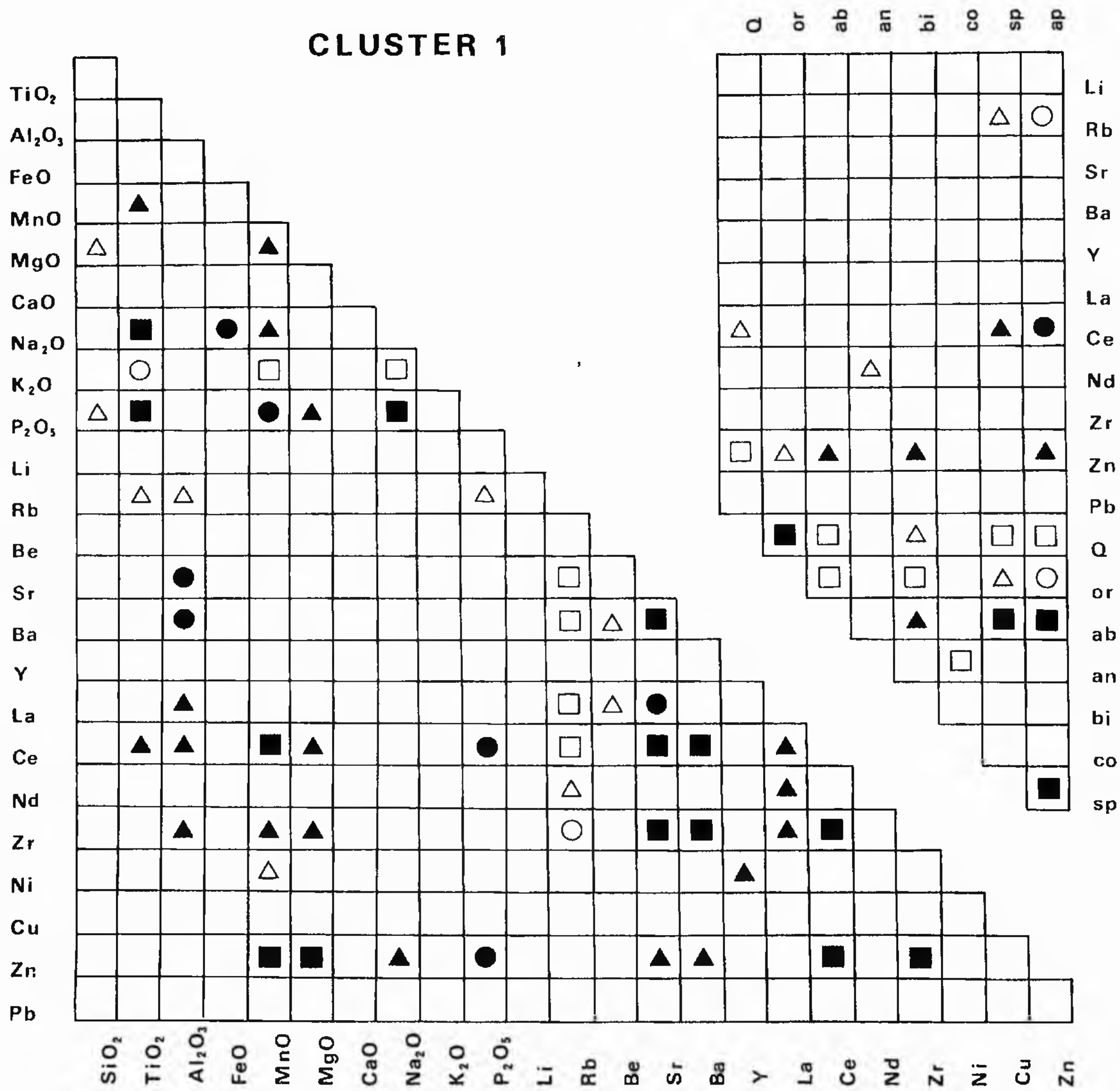
FIG. 84. CIPW-normative quartz (Q), alkali feldspar (or), plagioclase (ab + an) classification triangle adapted from I.U.G.S. Subcommission on the Systematics of Igneous rocks. The highest density of Fleet granite samples are indicated by field of horizontal shading.

FIG. 85. Top row, ternary diagrams of whole rock K_2O - Na_2O - CaO analyses. Left, coarse and fine grained granites; middle, coarse grained facies; right, fine grained facies. Ornament as in Fig. 86, position of triangle indicated on Fig. 50. Bottom row, ternary diagrams of whole rock Rb, Ba and Sr analyses. Triangles as above; ornament as in Fig. 86. Position of triangle showing coarse grained granite facies fields indicated on left triangle.
Apices are 100% of the component indicated except where otherwise stated.

FIG. 86. Ternary diagram of Rb, Sr and Zr whole rock analyses.

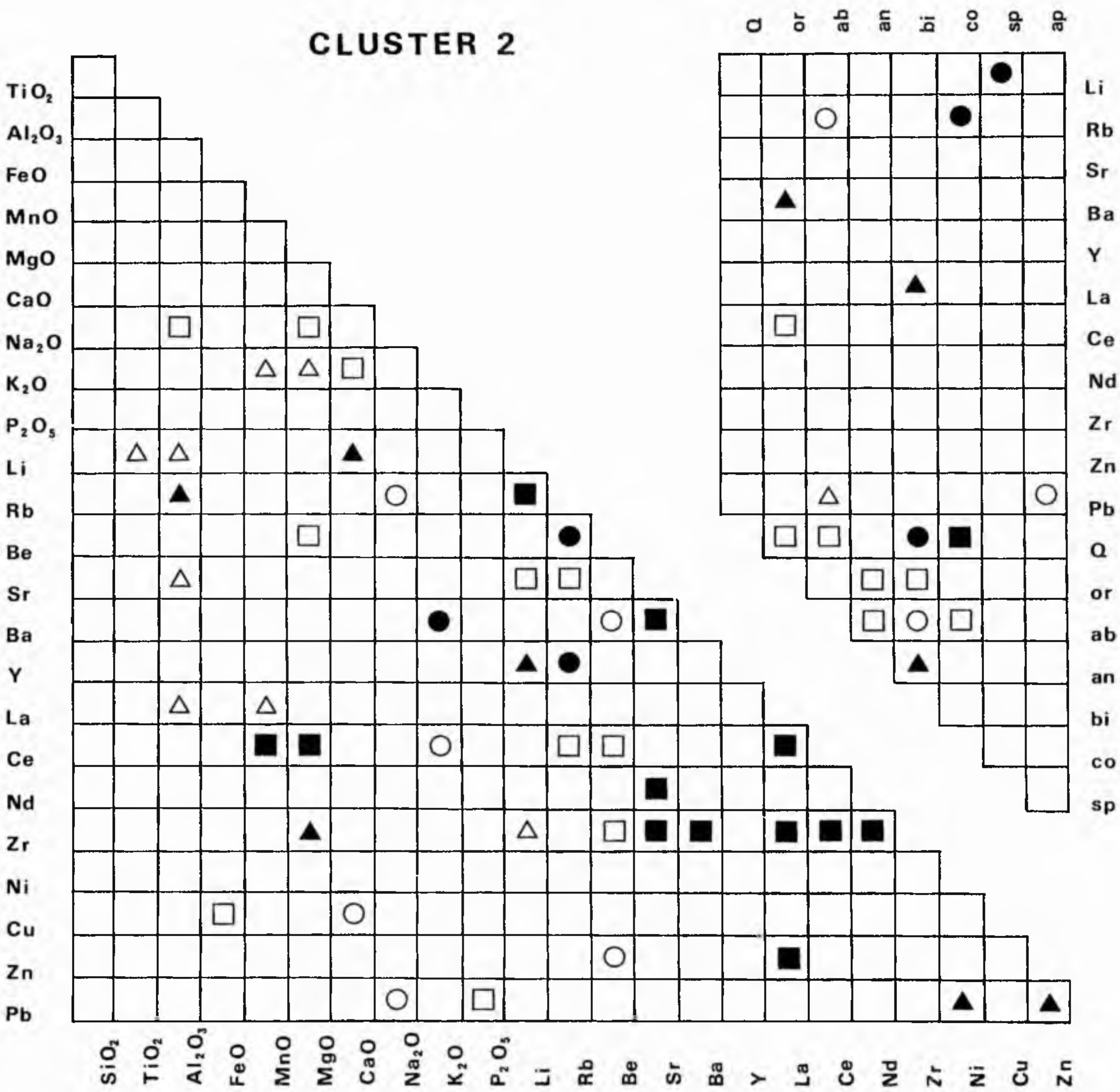

TOTAL
% significance
+99·5
+99·0
+97·5
-99·5
-99·0
-97·5
TiO2
Al2O3
FeO
MnO
MgO
CaO
Na2O
K2O
P2O5
Li
Rb
Be
Sr
Ba
Y
La
Ce
Nd
Zr
Ni
Cu
Zn
Pb
SiO2
Q
or
ab
an
bi
co
sp
ap

CLUSTER 1

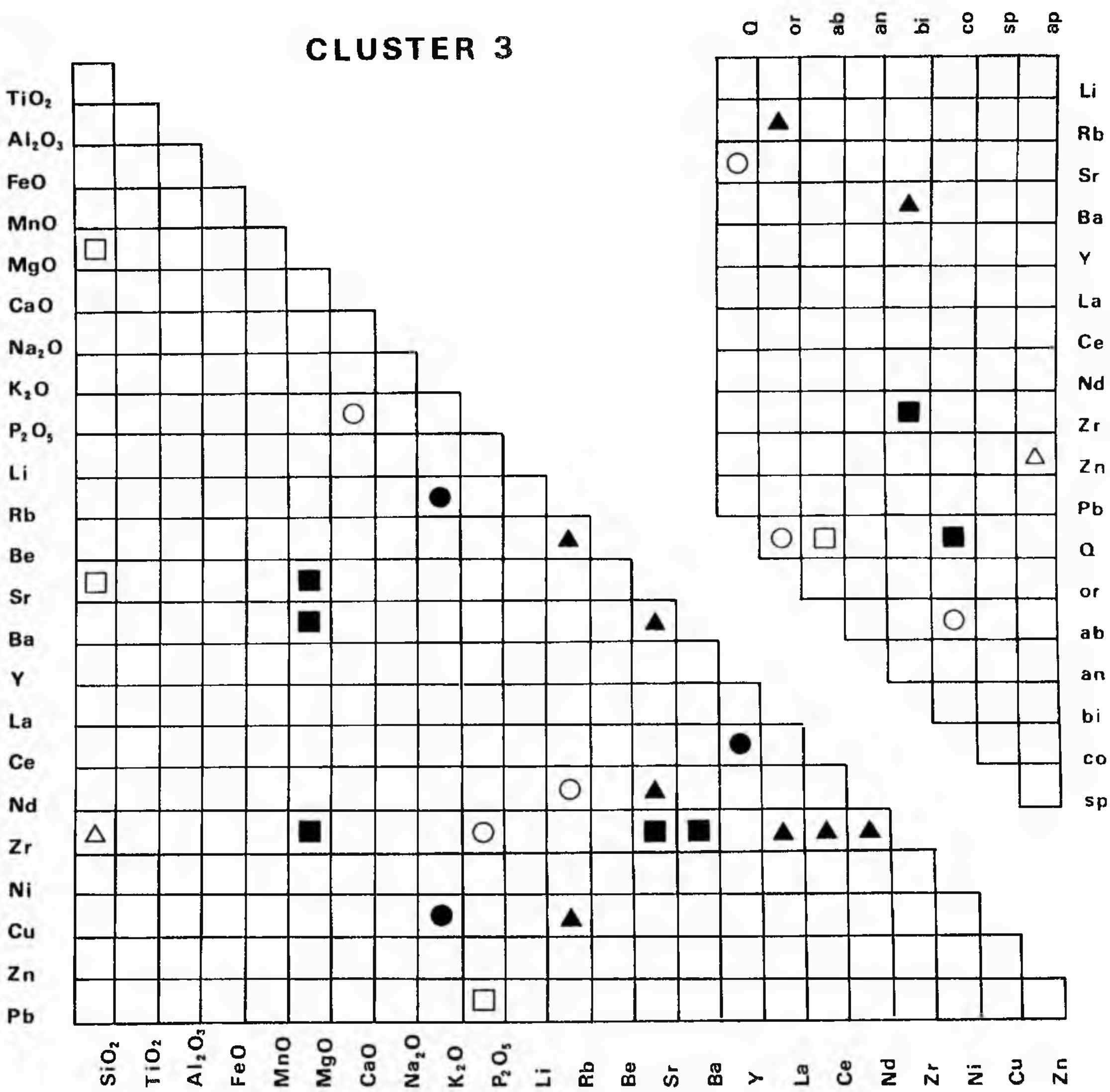


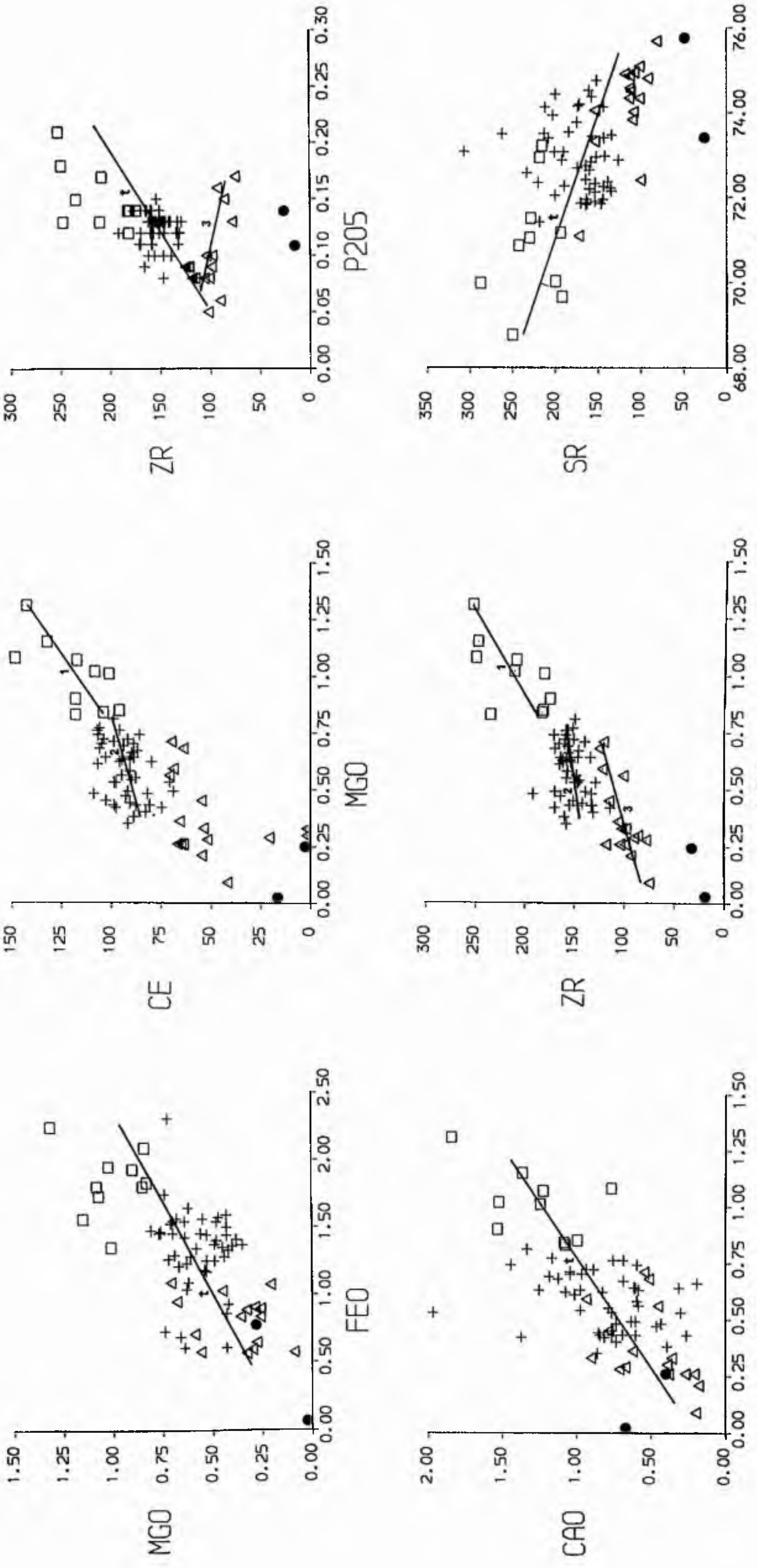
TiO2
Al2O3
FeO
MnO
MgO
CaO
Na2O
K2O
P2O5
Li
Rb
Be
Sr
Ba
Y
La
Ce
Nd
Zr
Ni
Cu
Zn
Pb
SiO2
TiO2
Al2O3
FeO
MnO
MgO
CaO
Na2O
K2O
P2O5
Li
Rb
Be
Sr
Ba
Y
La
Ce
Nd
Zr
Ni
Cu
Zn
Q
or
ab
an
bi
co
sp
ap
Li
Rb
Sr
Ba
Y
La
Ce
Nd
Zr
Zn
Pb
Q
or
ab
an
bi
co
sp

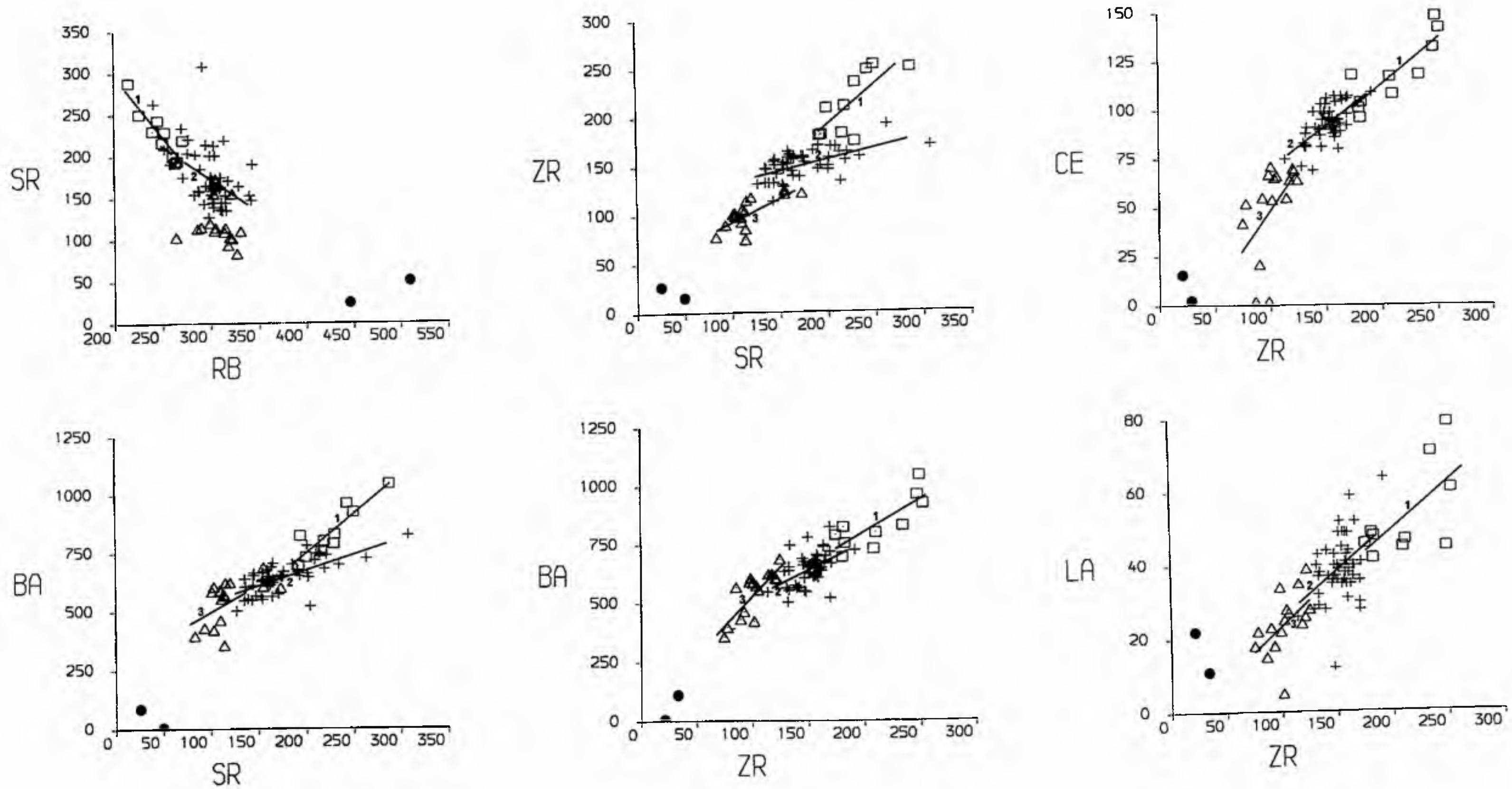
CLUSTER 2

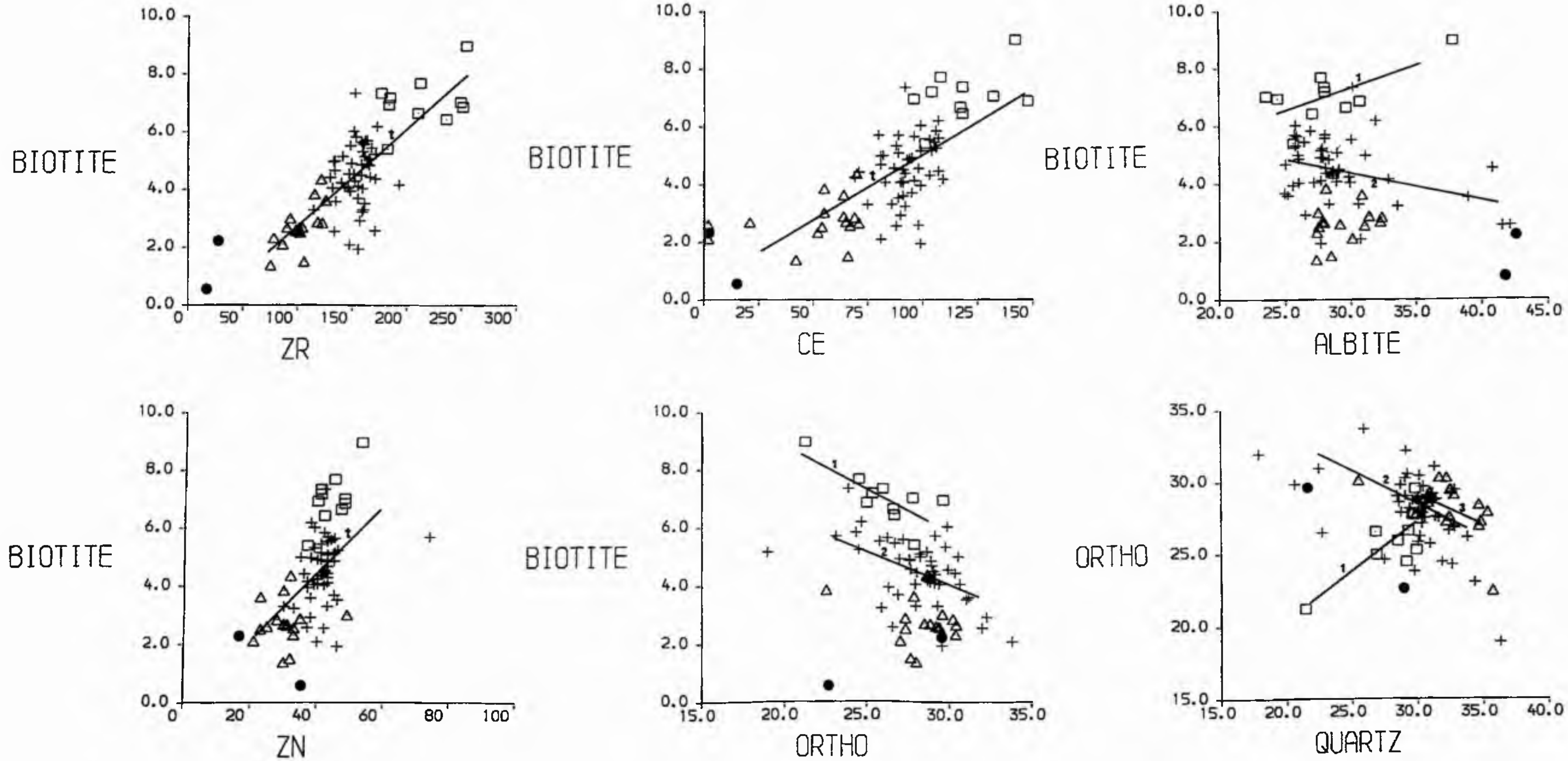


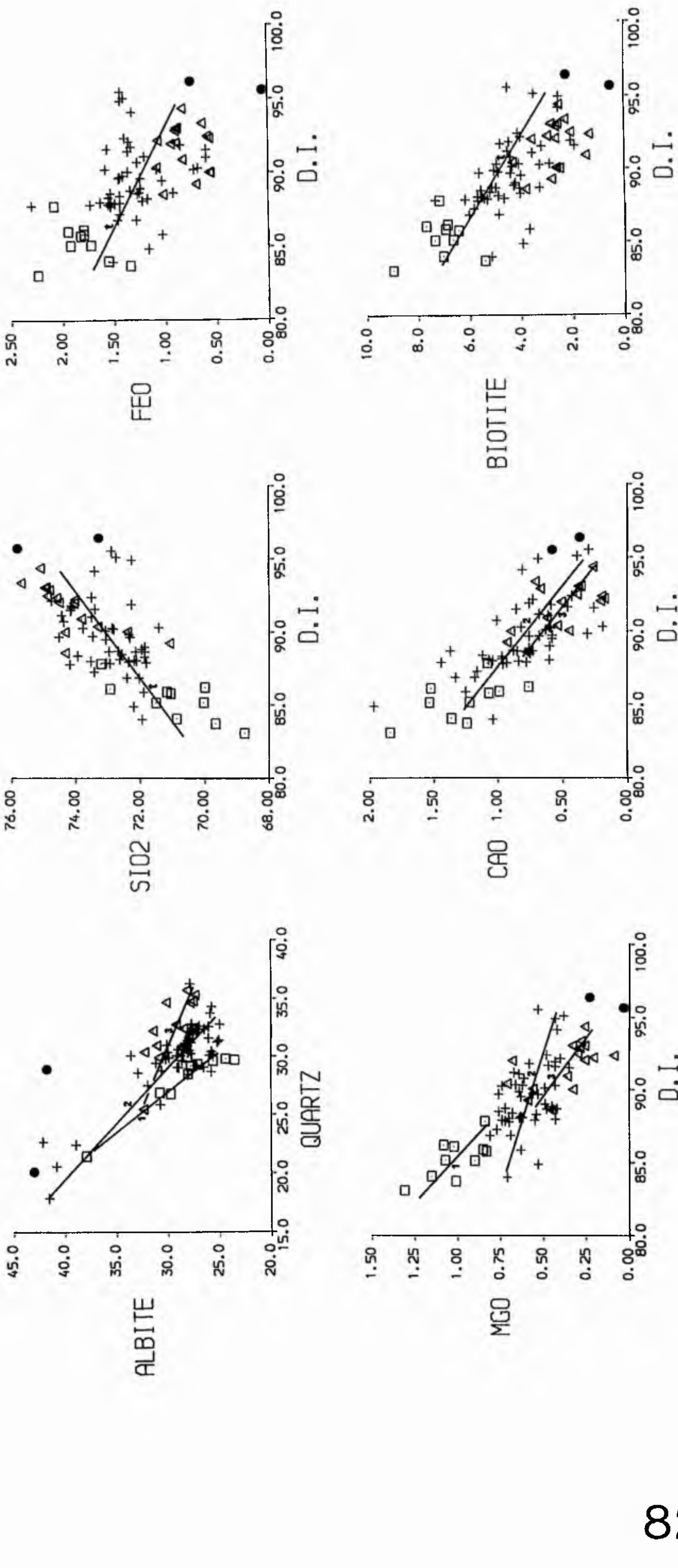
TiO2
Al2O3
FeO
MnO
MgO
CaO
Na2O
K2O
P2O5
Li
Rb
Be
Sr
Ba
Y
La
Ce
Nd
Zr
Ni
Cu
Zn
Pb
SiO2
Q
or
ab
an
bi
co
sp
ap

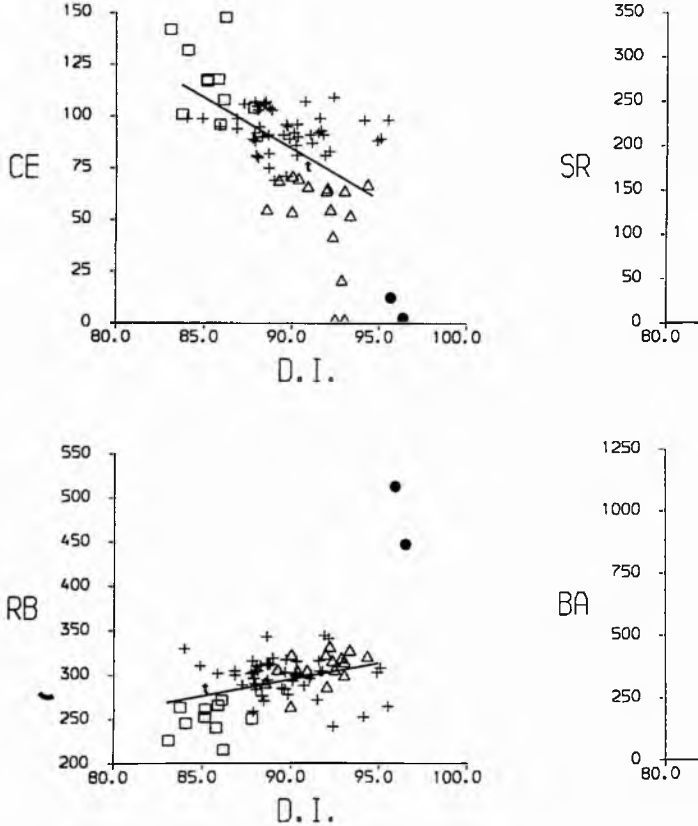

CLUSTER 3
TiO2
Al2O3
FeO
MnO
MgO
CaO
Na2O
K2O
P2O5
Li
Rb
Be
Sr
Ba
Y
La
Ce
Nd
Zr
Ni
Cu
Zn
Pb
SiO2
Q
or
ab
an
bi
co
sp
ap

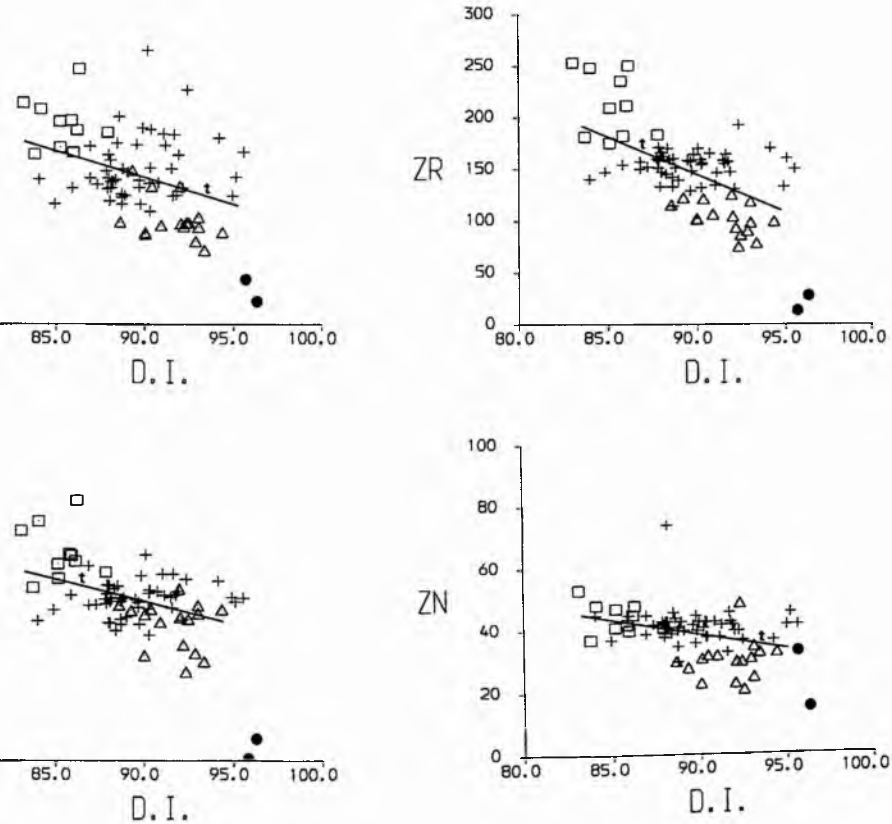

ZR
P2O5
CE
MGO
MGO
FEO
SR
SIO2
ZR
MGO
CAO
MGO


SR
RB
ZR
SR
CE
ZR
BA
SR
BA
ZR
LA
ZR


BIOTITE
ZR
BIOTITE
CE
BIOTITE
ALBITE
BIOTITE
ZN
BIOTITE
ORTHO
ORTHO
QUARTZ


ALBITE
QUARTZ
SIO2
D.I.
FEO
D.I.
MGO
D.I.
CAO
D.I.
BIOTITE
D.I.


CE
150
125
100
75
50
25
0
80.0
85.0
90.0
95.0
100.0
D.I.
SR
350
300
250
200
150
100
50
0
80.0
RB
550
500
450
400
350
300
250
200
80.0
85.0
90.0
95.0
100.0
D.I.
BA
1250
1000
750
500
250
0
80.0



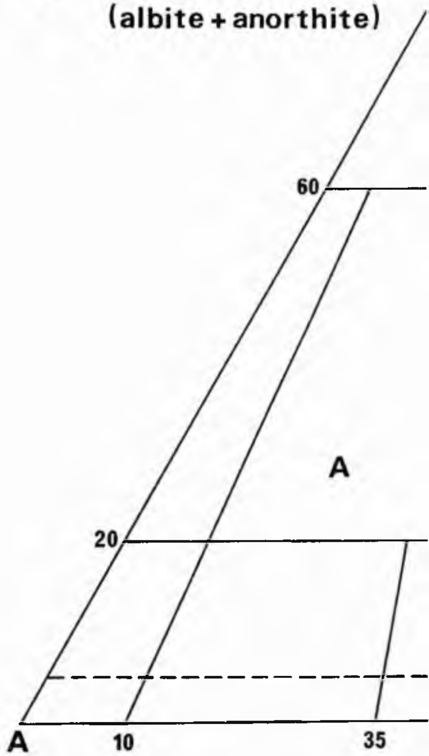
ZR
ZN
D.I.
D.I.
D.I.
D.I.

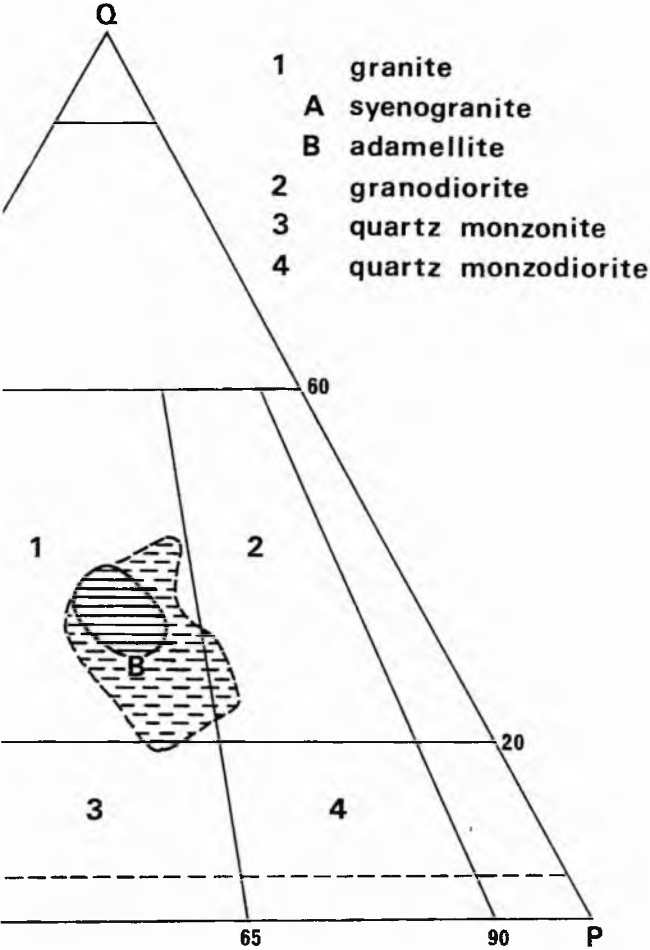
mesonormative minerals

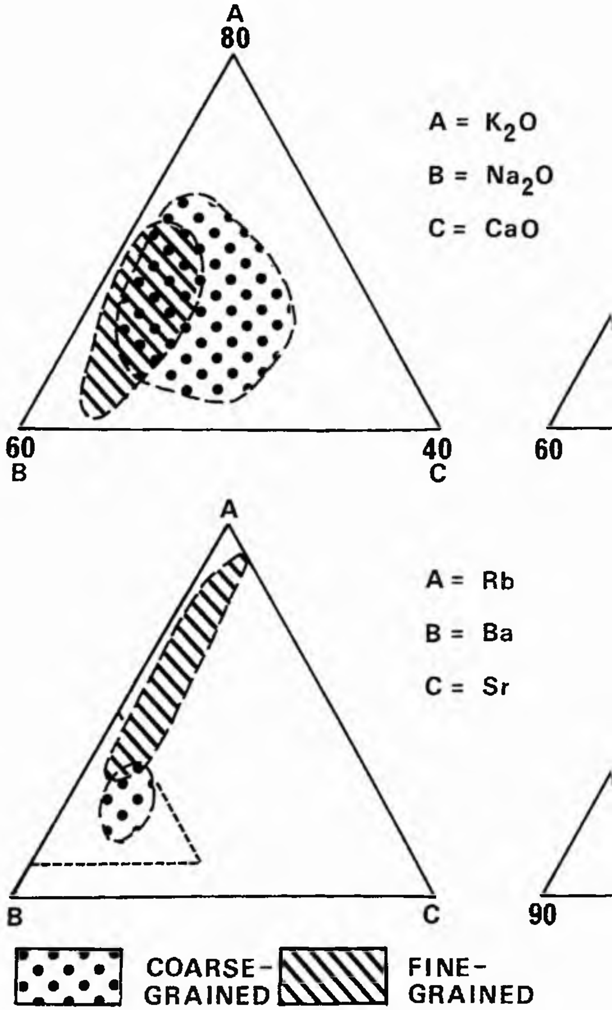
Q quartz

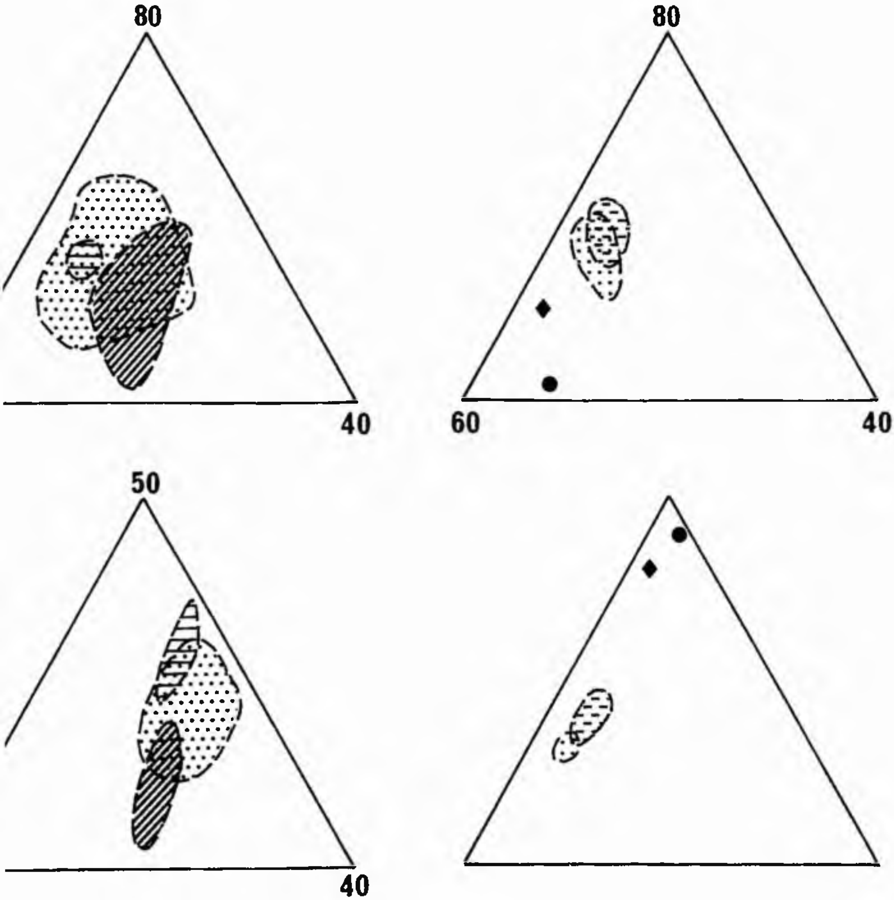
A alkali feldspar

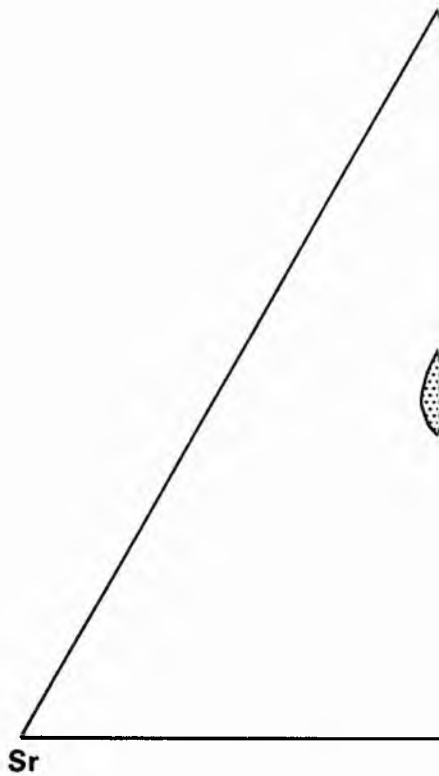
P plagioclase (albite + anorthite)

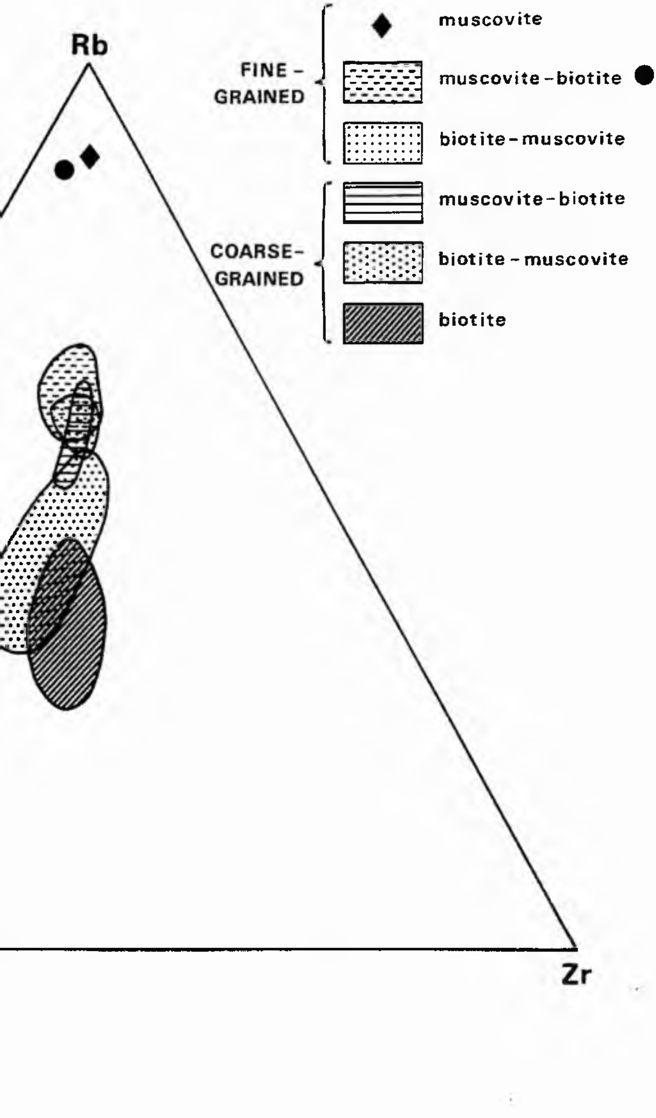



Q
1 granite
A syenogranite
B adamellite
2 granodiorite
3 quartz monzonite
4 quartz monzodiorite
60
1
2
B
20
3
4
65
90
P


A
80
A = K_2O
B = Na_2O
C = CaO
60
B
40
C
60
A
A = Rb
B = Ba
C = Sr
B
C
90
COARSE-
GRAINED
FINE-
GRAINED


80
40
80
60
40
50
40


Sr


Rb
Zr
FINE-GRAINED
muscovite
muscovite-biotite
biotite-muscovite
COARSE-GRAINED
muscovite-biotite
biotite-muscovite
biotite

FIGURES 87 - 89.

FIG. 87. A, field occupied by Fleet analyses in the 2000 bars isobaric equilibrium diagram for the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O, projected onto the anhydrous base of the $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O tetrahedron (after Tuttle and Bowen, 1958). * indicates highest density of sample points.

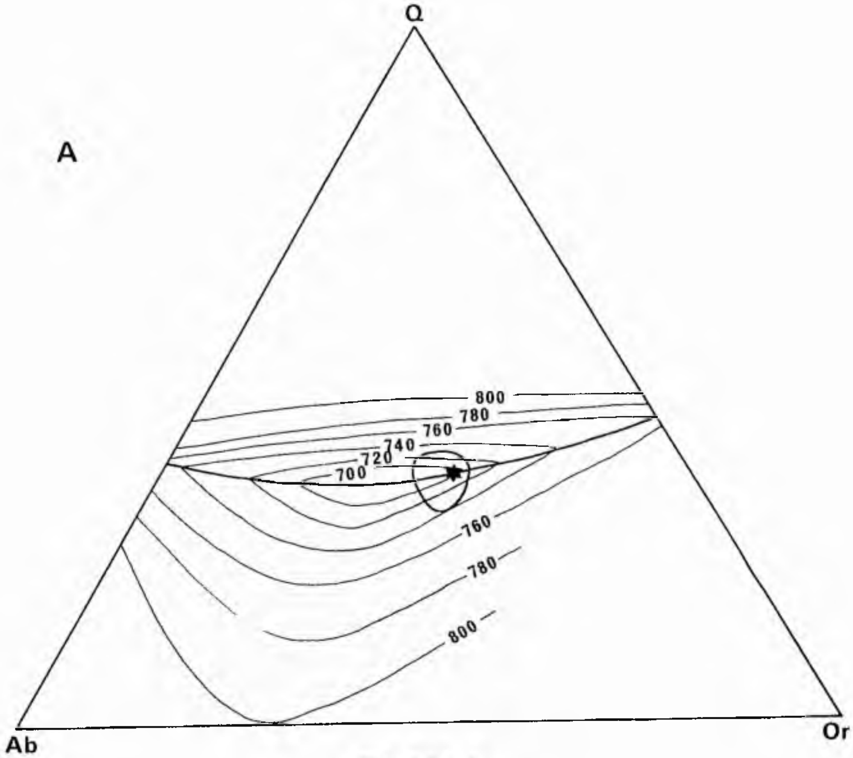
B, position of Fleet analyses in a section cut through the $CaAl_2Si_2O_8$-$NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2 tetrahedron at An 3 (1000 bars), (after James and Hamilton, 1969).

FIG. 88. A, field occupied by Fleet analyses in the ternary Q, Ab, Or system showing the effect of pH_2O on the isobaric minimum in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O, projected onto the anhydrous base of the tetrahedron (cf. Fig. 87A). Most granites plot in the shaded field (after Tuttle and Bowen, 1958).

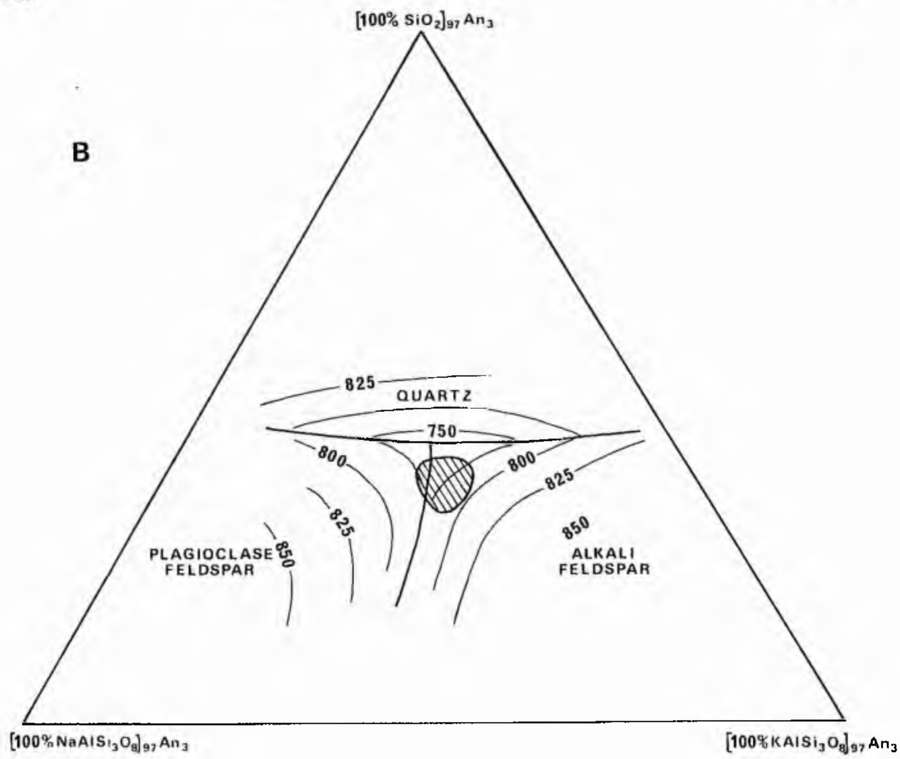
B, position of Fleet analyses on the an - ab - or face of the tetrahedron of the $CaAl_2Si_2O_8$-$NaAlSi_3O_8$ - $KAlSi_3O_8$-SiO_2 system, containing the univariant curve projected from the Q saturated surface (after James and Hamilton, 1969).

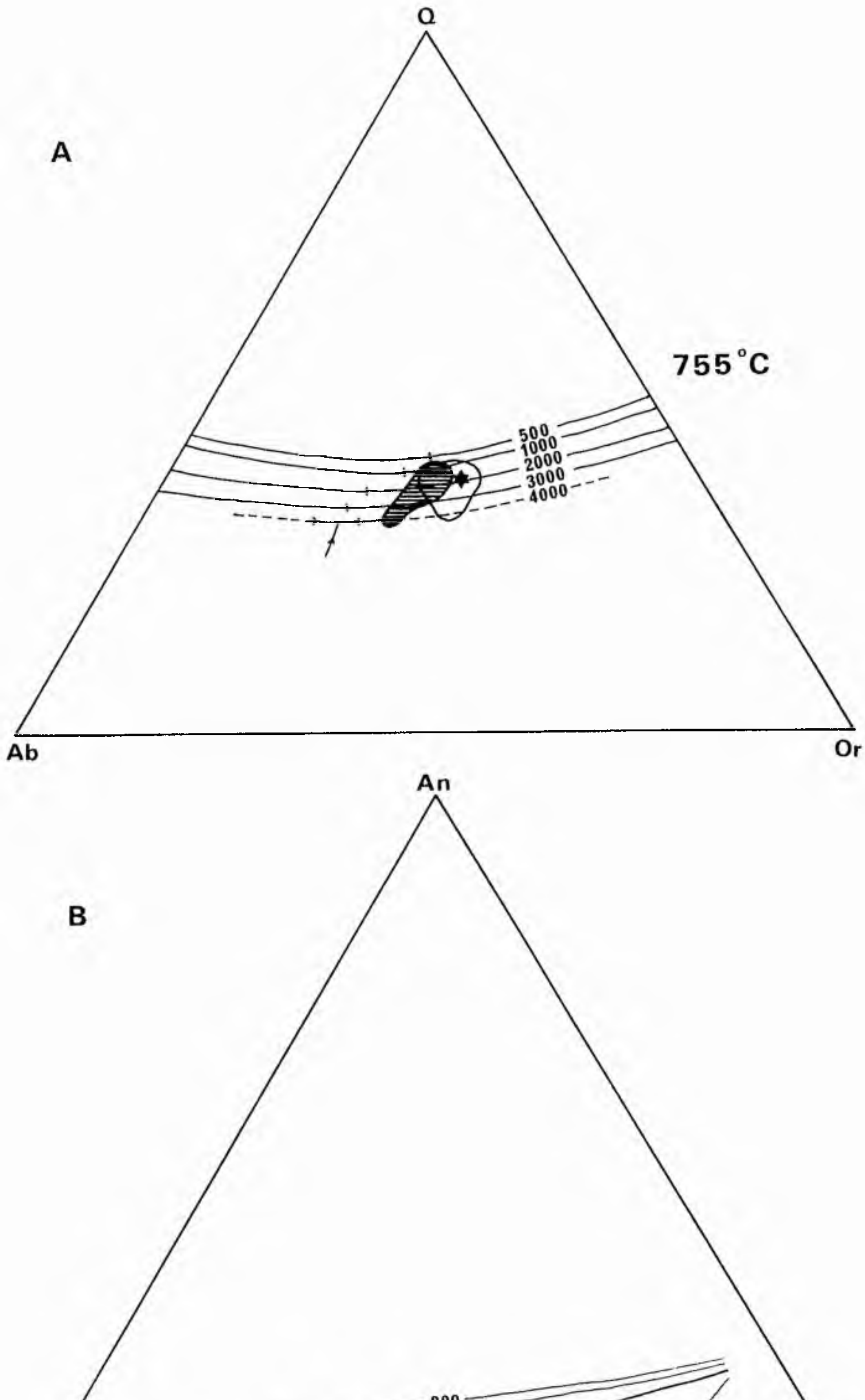
FIG. 89. Ternary diagrams of Rb, Sr and Zr, and CIPW normative an, ab and or analyses of minor intrusive rocks, compared with analyses of the Fleet granite (ornament as Fig. 85, dashed lines indicate albitization of samples from the same intrusive body).

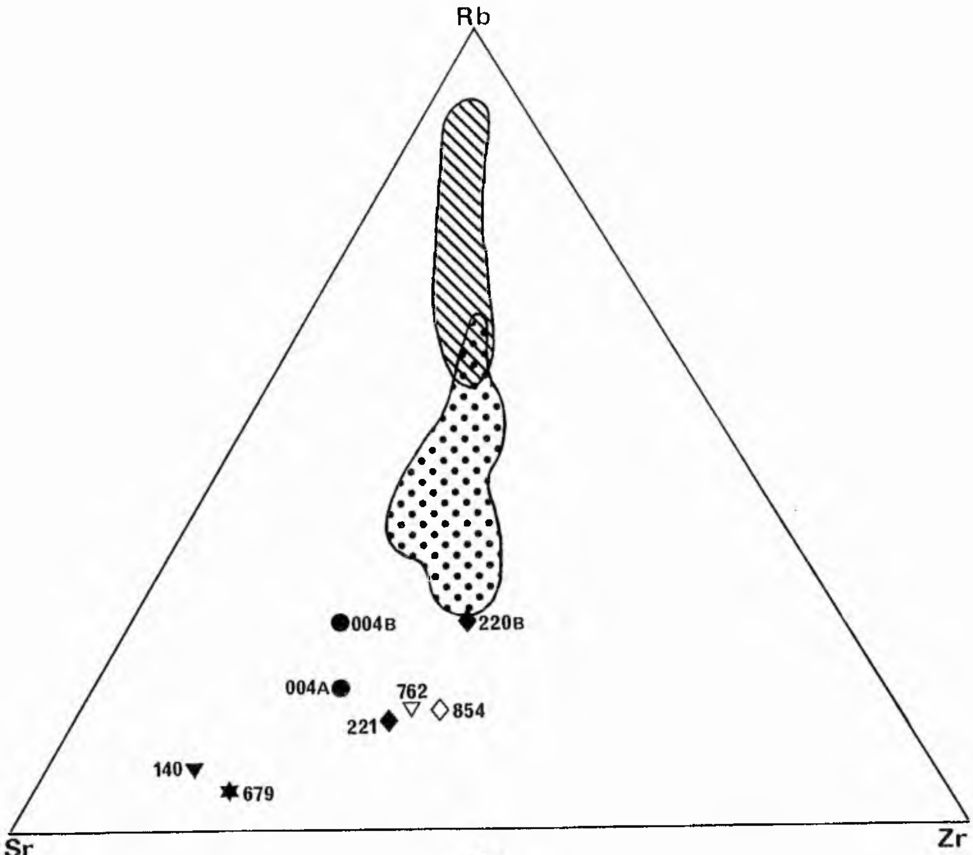
A

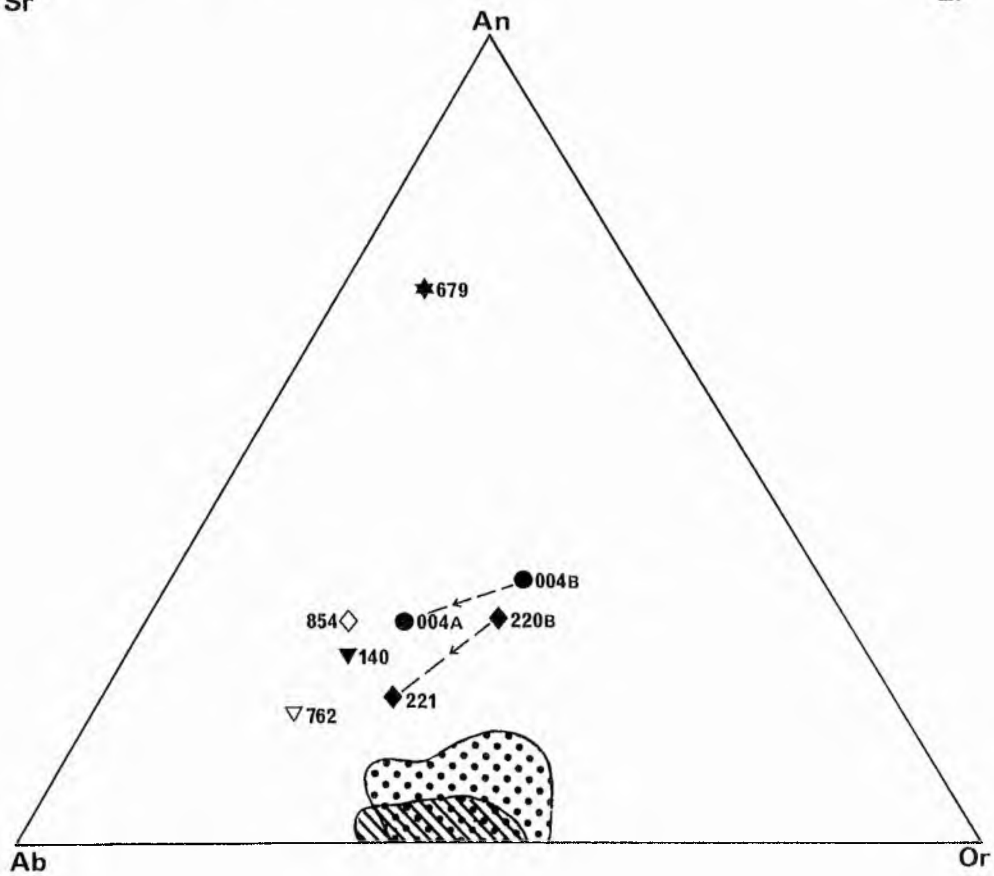

Q
800
780
760
740
720
700
760
780
800
Ab
Or

B


[100% SiO_2]$_{97}$ An_3
825
QUARTZ
750
800
800
825
825
850
850
PLAGIOCLASE FELDSPAR
ALKALI FELDSPAR
[100% $NaAlSi_3O_8$]$_{97}$ An_3
[100% $KAlSi_3O_8$]$_{97}$ An_3


Q
A
755°C
500
1000
2000
3000
4000
Ab
Or
An
B
800
775
750
750
775
Ab
Or


Rb
004B
220B
004A
762
854
221
140
679
Sr
Zr


An
679
004B
854
004A
220B
140
221
762
Ab
Or

FIGURES 90 - 97.

FIG. 90. Localities of mineralization within the Southern Uplands. Plutonic masses, dashed ornament; post Lower Palaeozoic strata, stippled ornament.

FIG. 91. Localities of mineralization and mineral zones in the Fleet orefield. Major ore metals indicated by their chemical symbols; gangue, C = calcite, ferroan calcite, ankerite or dolomite, B = barytes, Q = quartz. Locality numbers are given in the text.

FIG. 92. Minerals in the Fleet orefield. ■ = major constituent, ▲ = minor constituent.

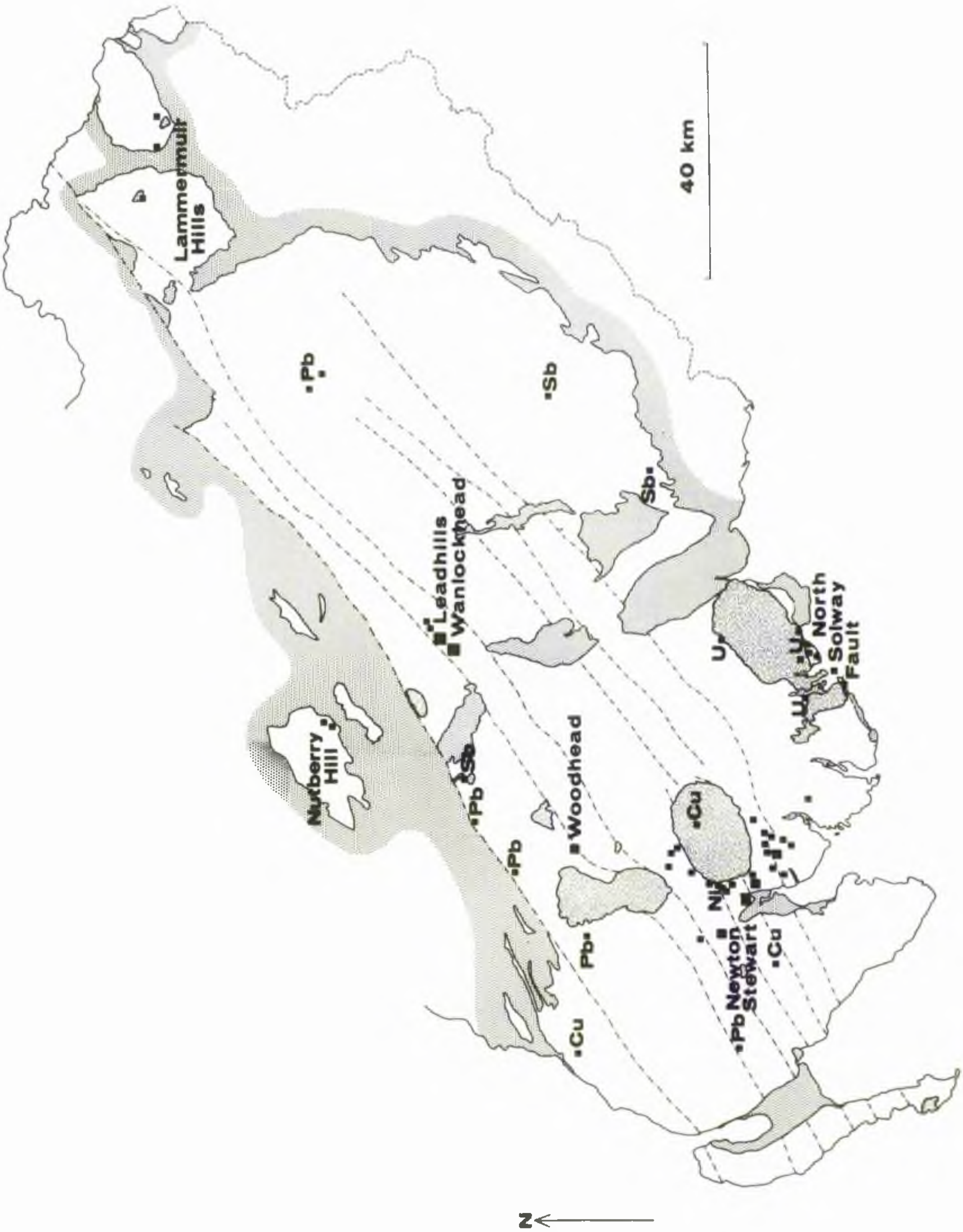
FIG. 93. Rose diagram of trends of mineral veins; fields indicate the proportion of major ore metal components.

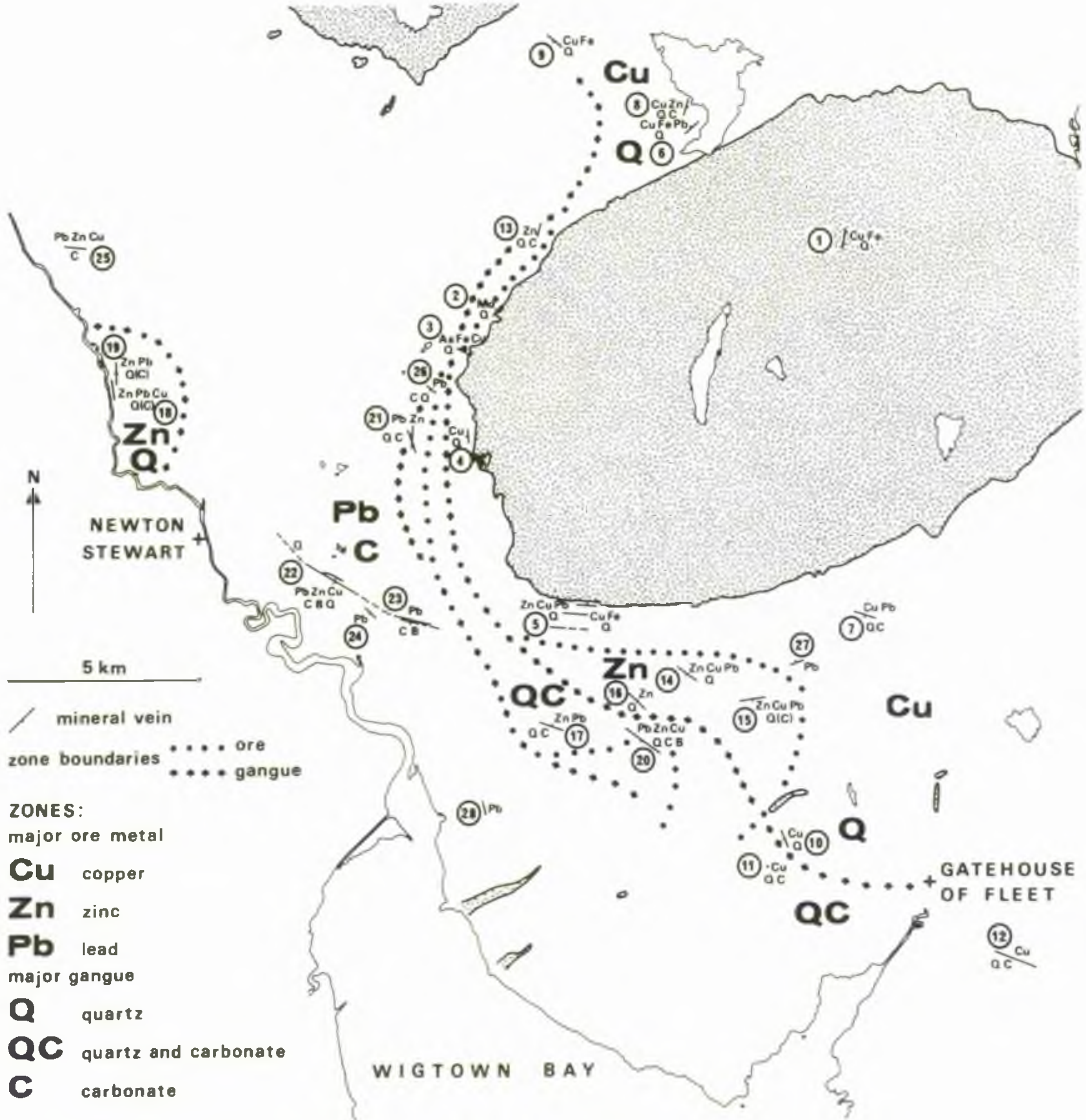
FIG. 94. Ore metal and gangue zones of the Fleet orefield (country rocks only).

FIG. 95. Talnotry veins.

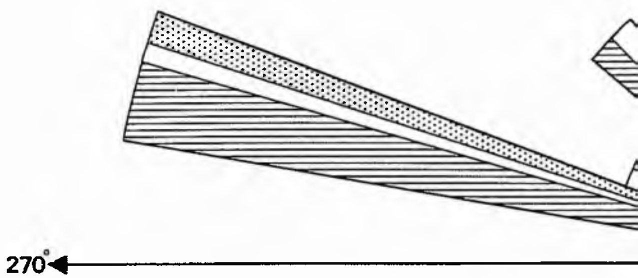
FIG. 96. Wood of Cree and Coldstream Burn veins (ornament as Figs. 95 and 97).

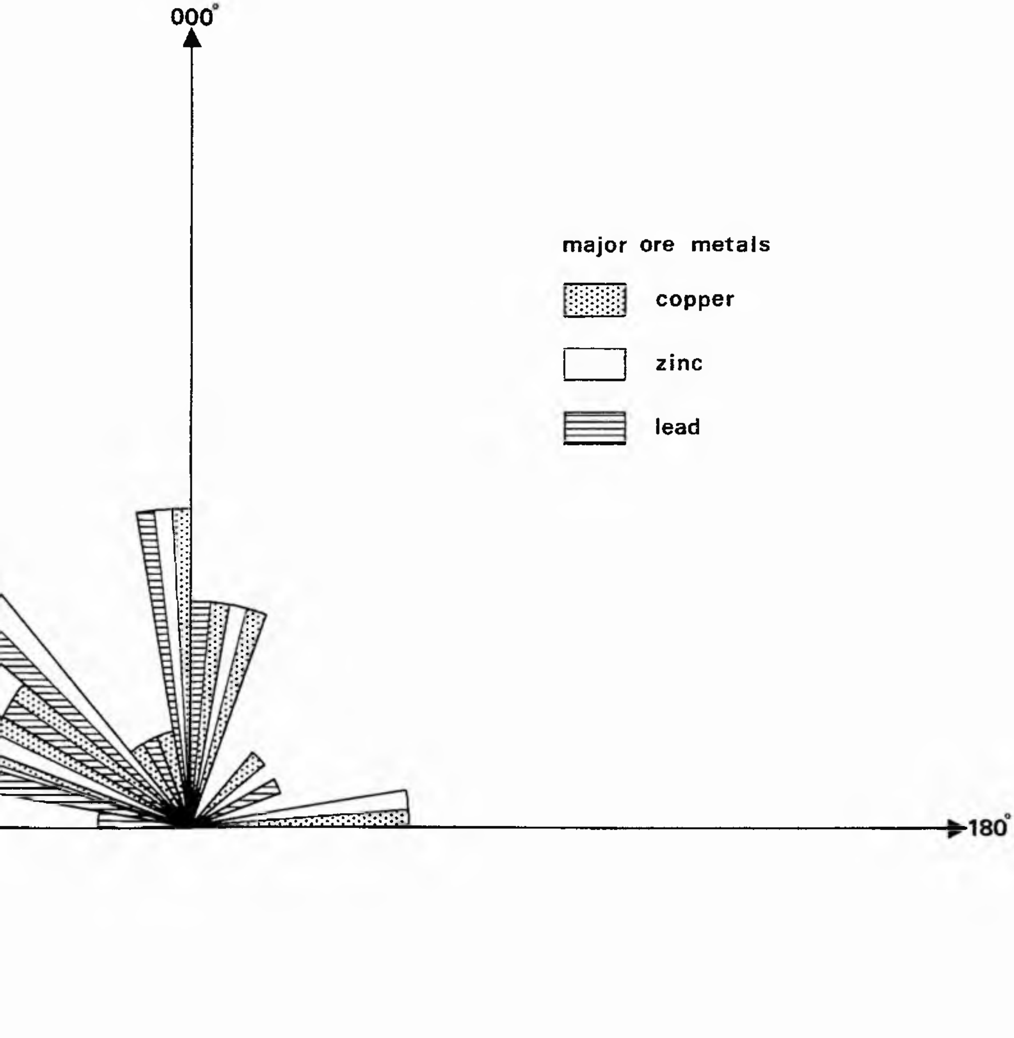
FIG. 97. Pibble Mine.


Lammermuir Hills
40 km
Pb
Sb
Sb
Leadhills
Wanlockhead
U
U
U
North Solway Fault
Nutberry Hill
Pb
Sb
Pb
Woodhead
Cu
Pb
Ni
Newton Stewart
Cu
Cu
Pb
N

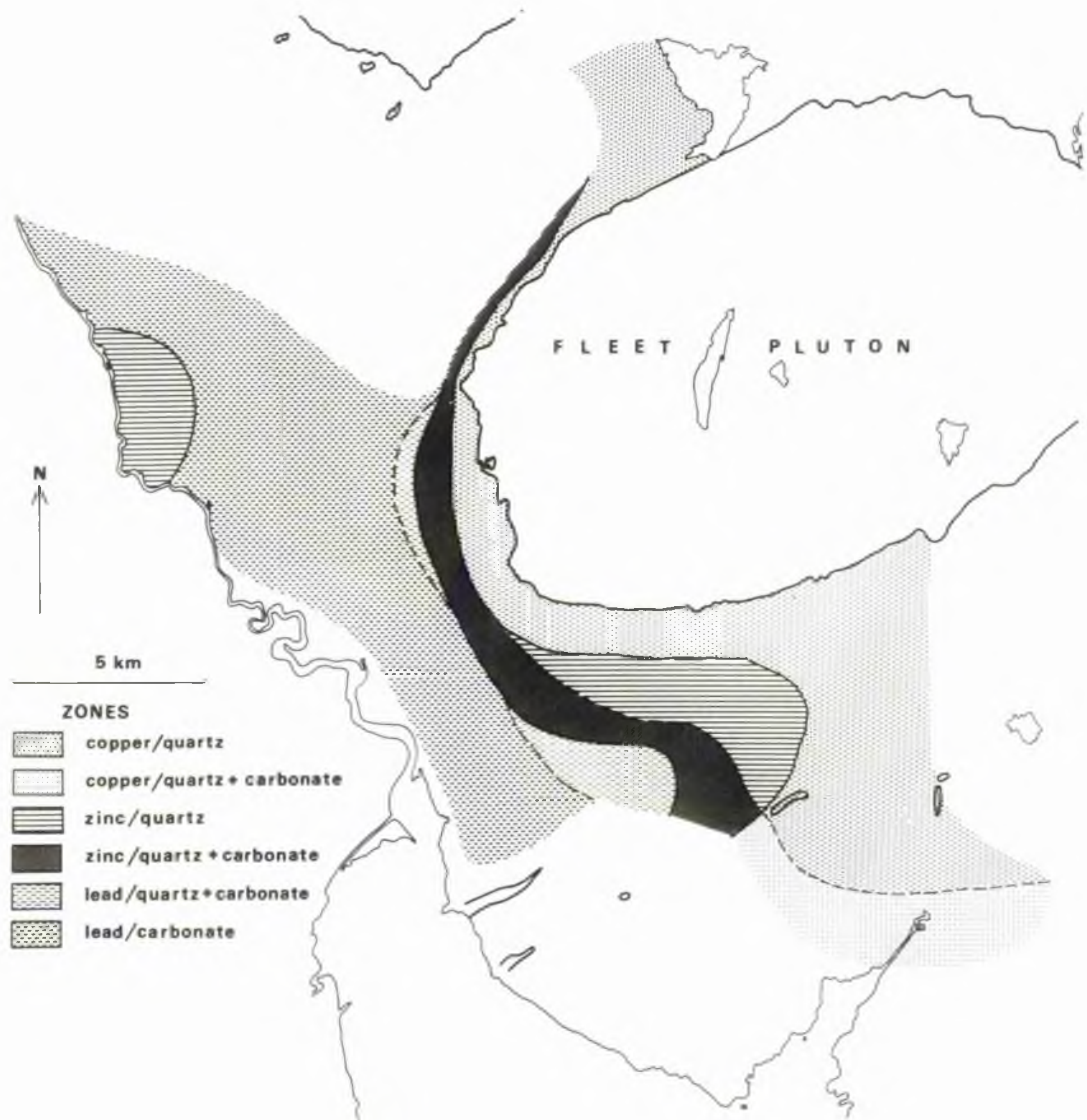

Cu
Q
Zn
Q
Pb
C
QC
Zn
Cu
Q
QC
NEWTON
STEWART
GATEHOUSE
OF FLEET
WIGTOWN BAY
N
5 km
mineral vein
zone boundaries
ore
gangue
ZONES:
major ore metal
Cu copper
Zn zinc
Pb lead
major gangue
Q quartz
QC quartz and carbonate
C carbonate

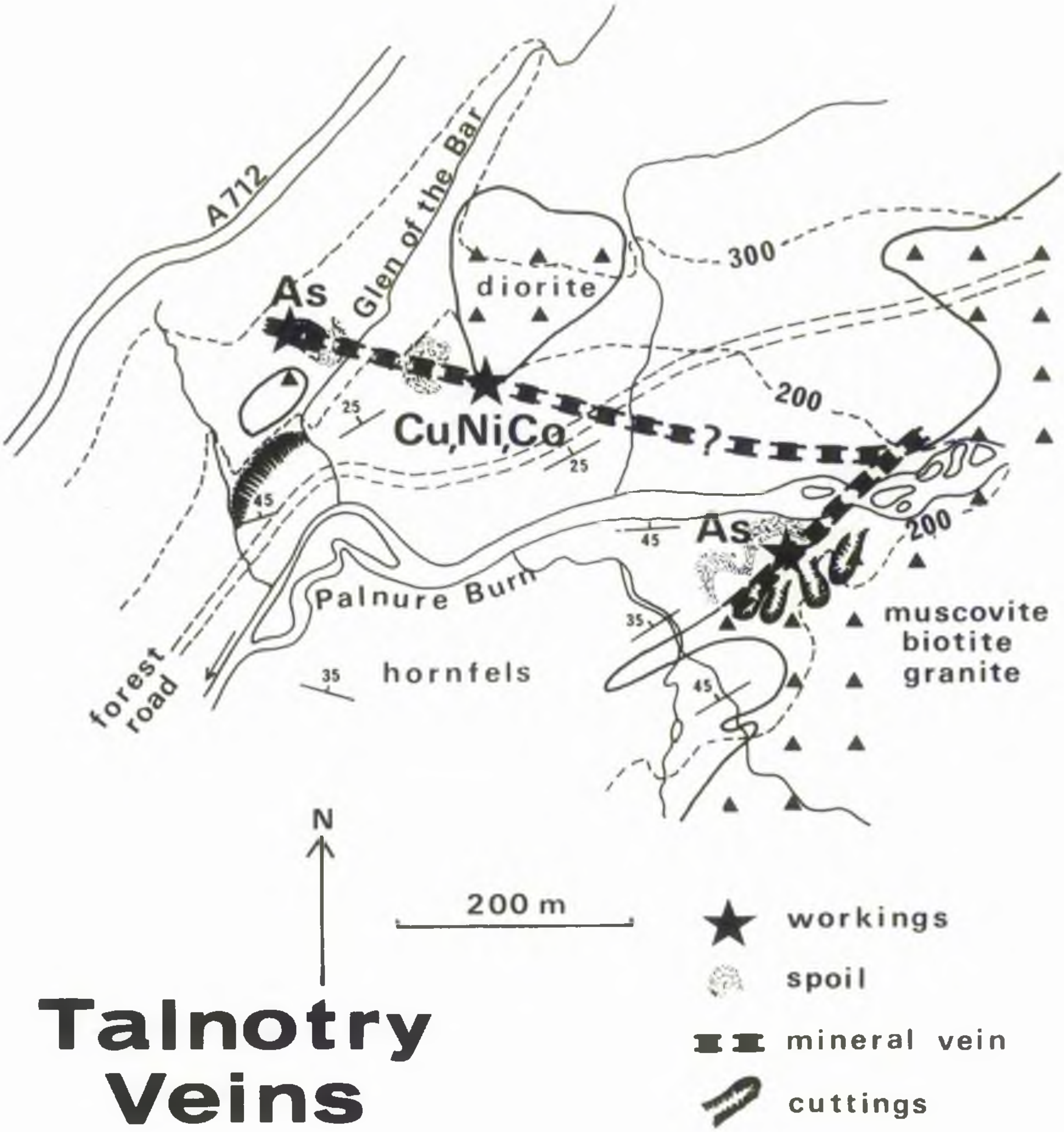
	1. ORCHARS	2. CLUGIE LINN	3. TALNOTRY	4. BLAIRBUIES	5. CULCRONCHIE	6. CLATTERINGSHAWS	7. DRUMRUCK	8. CRAIGNELL	9. CRAIGENCALLIE	10. KINGS LAGGAN	11. LAUCHENTYRE	12. ENRICK	13. TONDERGHIE	14. DROMORE	15. MEIKLE BENNAN	16. PIBBLE GULCH	17. CHAIN BURN	18. WOOD OF CREE	19. COLDSTREAM BURN	20. PIBBLE	21. BARGALY	22. BLACKCRAIG	23. CAIRNSMORE	24. SILVER RIGG	25. DALLASH
PYRITE	■		▶		▶	▶			▶				▶	▶	▶			▶	▶		▶	▶	▶	▶	▶
PYRRHOTITE			■			▶																			
PENTLANDITE			▶																						
MOLYBDENITE		▶																							
CHALCOPYRITE	▶		■	▶	■	▶	■	■	■	■	■	■	▶	▶	▶		▶	▶	▶	■	▶	▶		▶	▶
SPHALERITE					■			▶			▶		■	■	■	■	■	■	■	■	■	■		■	▶
GALENA					▶	▶	▶						▶	■	▶		▶	■	■	■	■	■	■	■	■
ARSENOPYRITE			■																						
SMALTITE			▶																						
NICCOLITE			▶														▶			▶					
HEMATITE	▶																								
COLLOFORM SILICA	■				▶									▶						▶	▶				
QUARTZ	■	■	▶	■	■	■	■	■	■	■	■	■	■	■	■	■	■	▶	▶	■	■	▶			▶
CALCITE					▶	▶		■			▶	▶	■	▶	▶		▶	▶	▶	▶	▶	■	■	■	■
DOLOMITE											▶									▶	■	■	■	▶	
ANKERITE							▶			▶			▶		▶		▶			■		■		■	▶
SIDERITE																	▶			▶	▶				
BARYTES																				▶		▶	▶		
LIMONITE																				▶	▶				
NATIVE SILVER																				▶					
NATIVE COPPER																				▶					
CHALCOCITE					▶		▶			▶										▶					
COVELLITE							▶													▶					
REALGAR			▶																						
ORPIMENT			▶																						
CUPRITE							▶			▶										▶					
TENORITE							▶			▶															
MALACHITE										▶	▶	▶								▶					
AZURITE											▶									▶					
CERUSSITE																				▶		▶			
SMITHSONITE																				▶					
ANGLESITE																				▶		▶			
CRYSOCOLLA							▶			▶										▶					
HEMIMORPHITE																				▶					
ERYTHRITE																						▶			
ANNABERGITE																				▶					
DUDGEONITE																				▶					
LEADHILLITE																				▶					
LINARITE																				▶					
PYROMORPHITE																			▶	▶					


270°

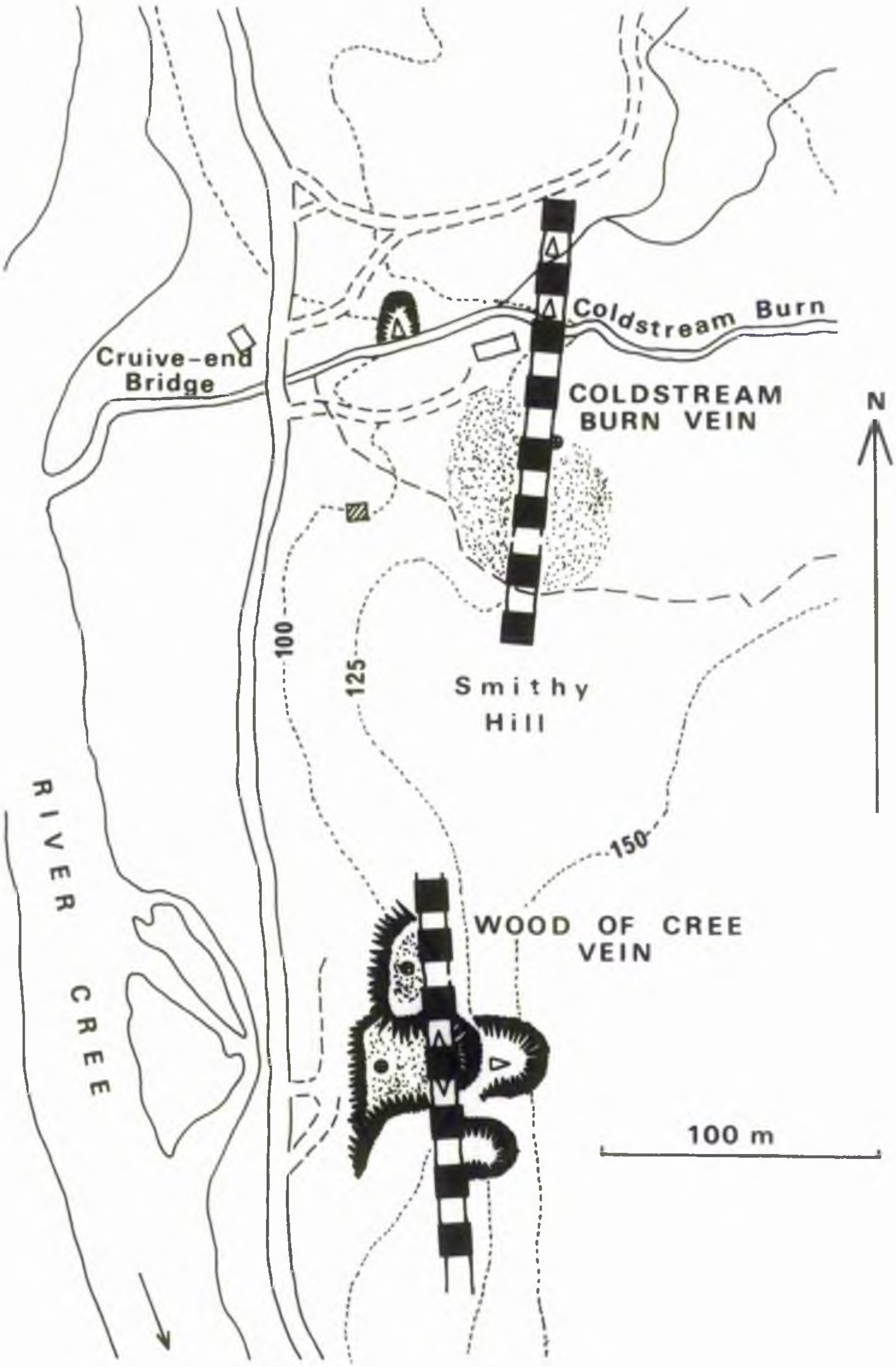


000°
180°
major ore metals
copper
zinc
lead

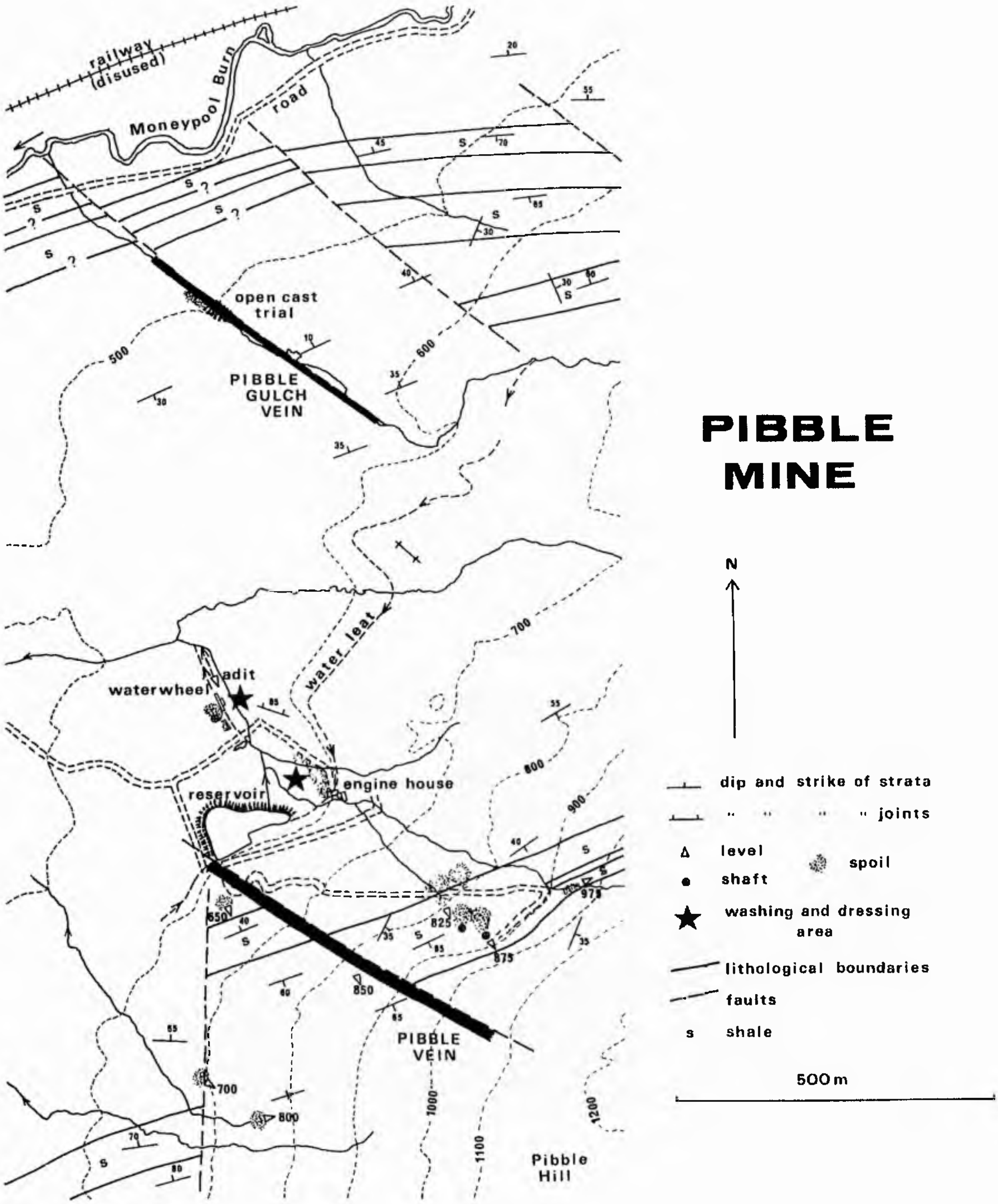

FLEET PLUTON
N
5 km
ZONES
copper/quartz
copper/quartz + carbonate
zinc/quartz
zinc/quartz + carbonate
lead/quartz + carbonate
lead/carbonate



Talnotry Veins


Coldstream Burn
Cruive-end Bridge
COLDSTREAM BURN VEIN
N
100
125
Smithy Hill
150
RIVER CREE
WOOD OF CREE VEIN
100 m

PIBBLE MINE


railway (disused)
Moneypool Burn
road
open cast trial
PIBBLE GULCH VEIN
500
600
700
800
900
1000
1100
1200
water leat
adit
waterwheel
engine house
reservoir
PIBBLE VEIN
Pibble Hill
N
dip and strike of strata
" " " " joints
level
shaft
spoil
washing and dressing area
lithological boundaries
faults
s shale
500 m

FIGURES 98 - 104.

FIGS. 98 and 99. Sample locations of sulphide minerals analysed; chalcopyrite (Fig. 98), galena and sphalerite (Fig. 99). See appendix 10.

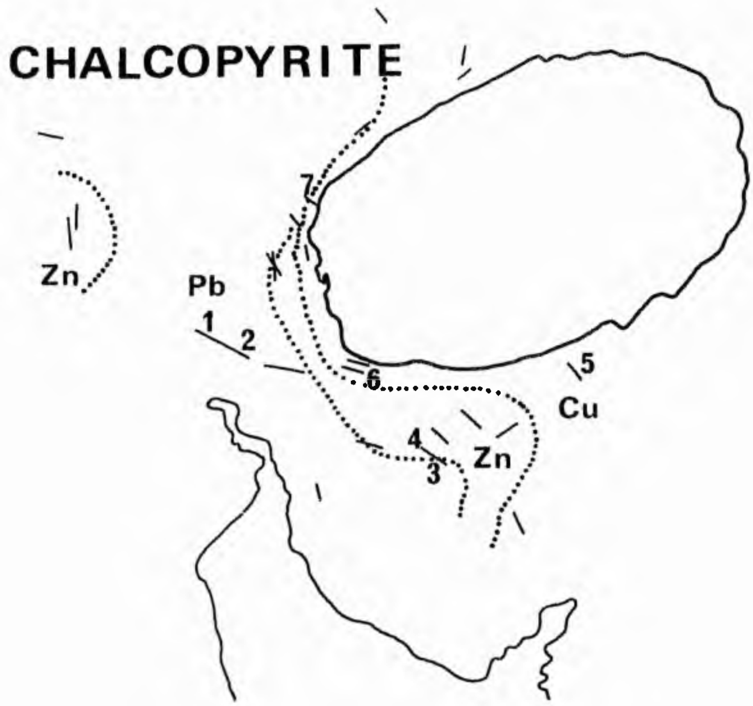
FIG. 100. Dendrogram from cluster analysis of sphalerite geochemical data. ▲ = lead zone, ◆ = zinc zone and ● = copper zone.

FIG. 101. Bar diagrams of the content of various elements within galena, sphalerite and chalcopyrite from the Fleet orefield. Minerals from the copper zone = ●, zinc zone = ◆ and lead zone = ▲ . Ranges in element content of zinc zone sphalerites from the Wood of Cree area = W, and Pibble area = P. Sample numbers from Fig. 98.

FIG. 102. Ternary diagram of the Zn, Fe and Cd contents of sphalerites (ornament as Fig. 103) and galenas (✱). Sample numbers from Fig. 98.

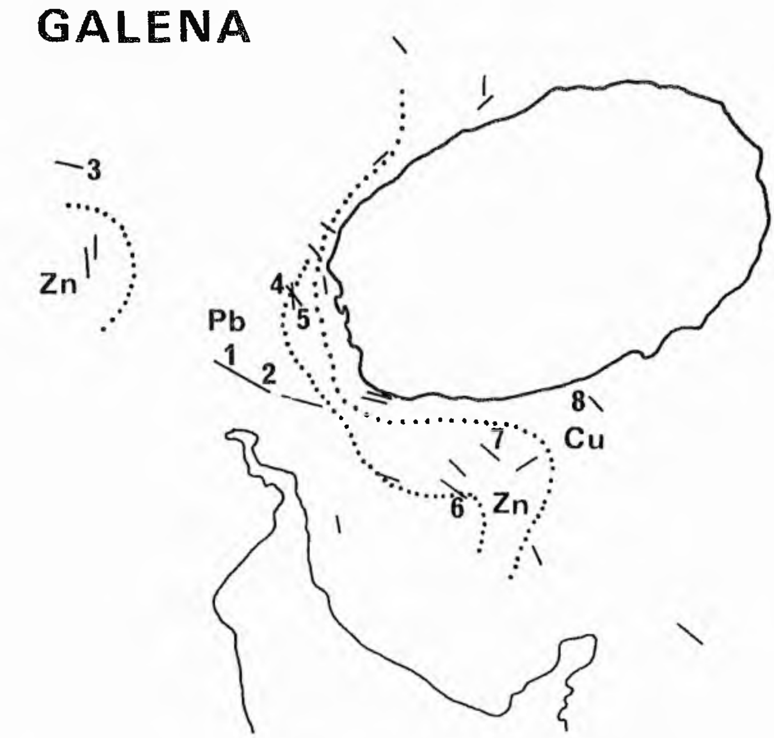
FIG. 103. Ternary diagrams of Cd, Ag and Co, and Cd, Mn and Co analyses of sphalerites.

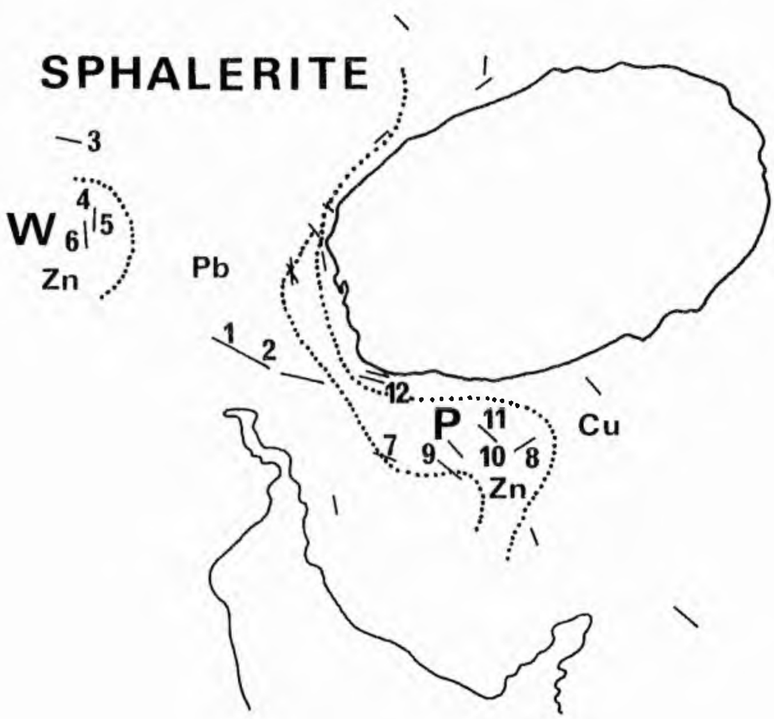
FIG. 104. Ternary diagram of the Ni, Ag and Co contents of chalcopyrites.

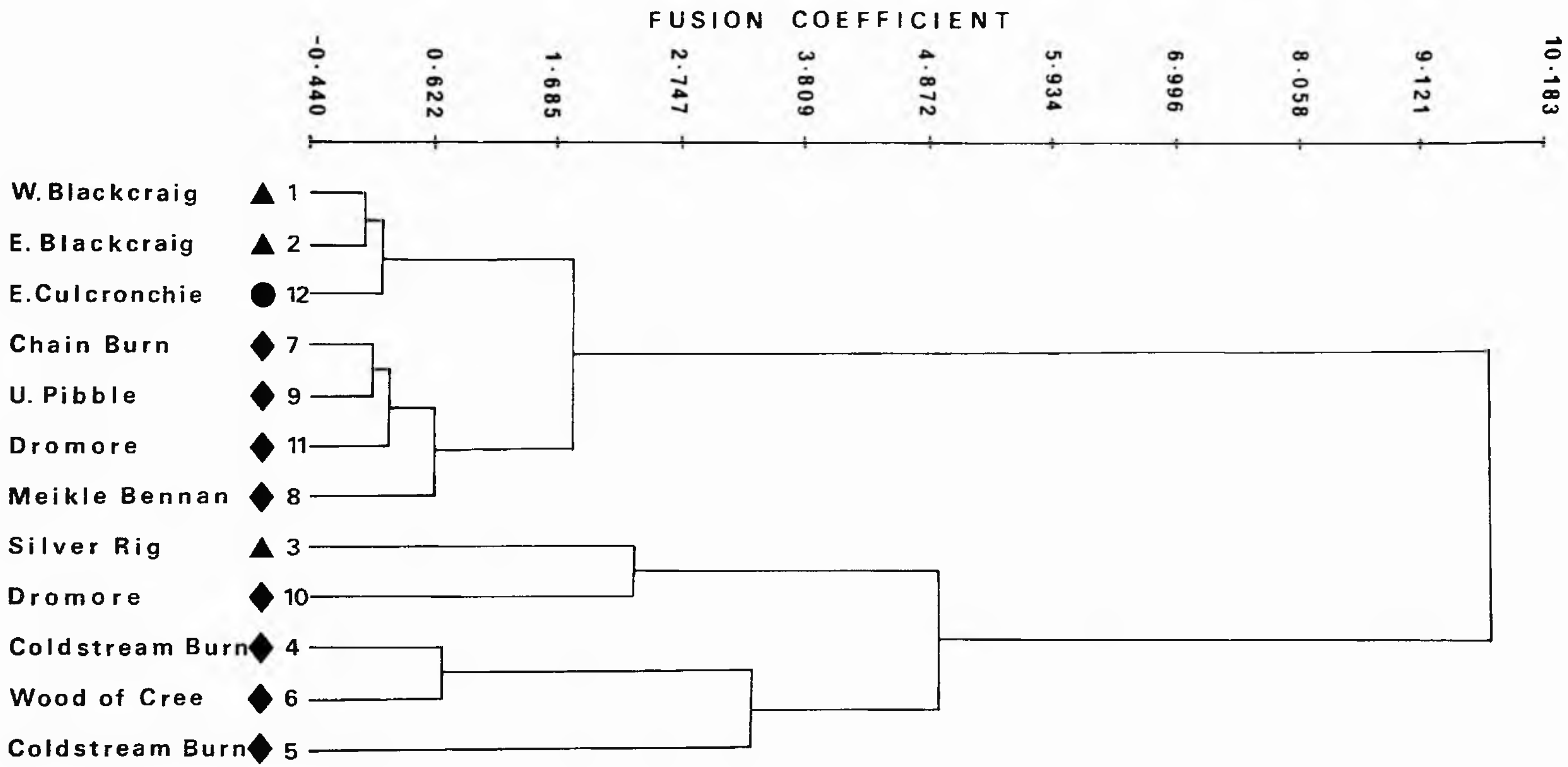


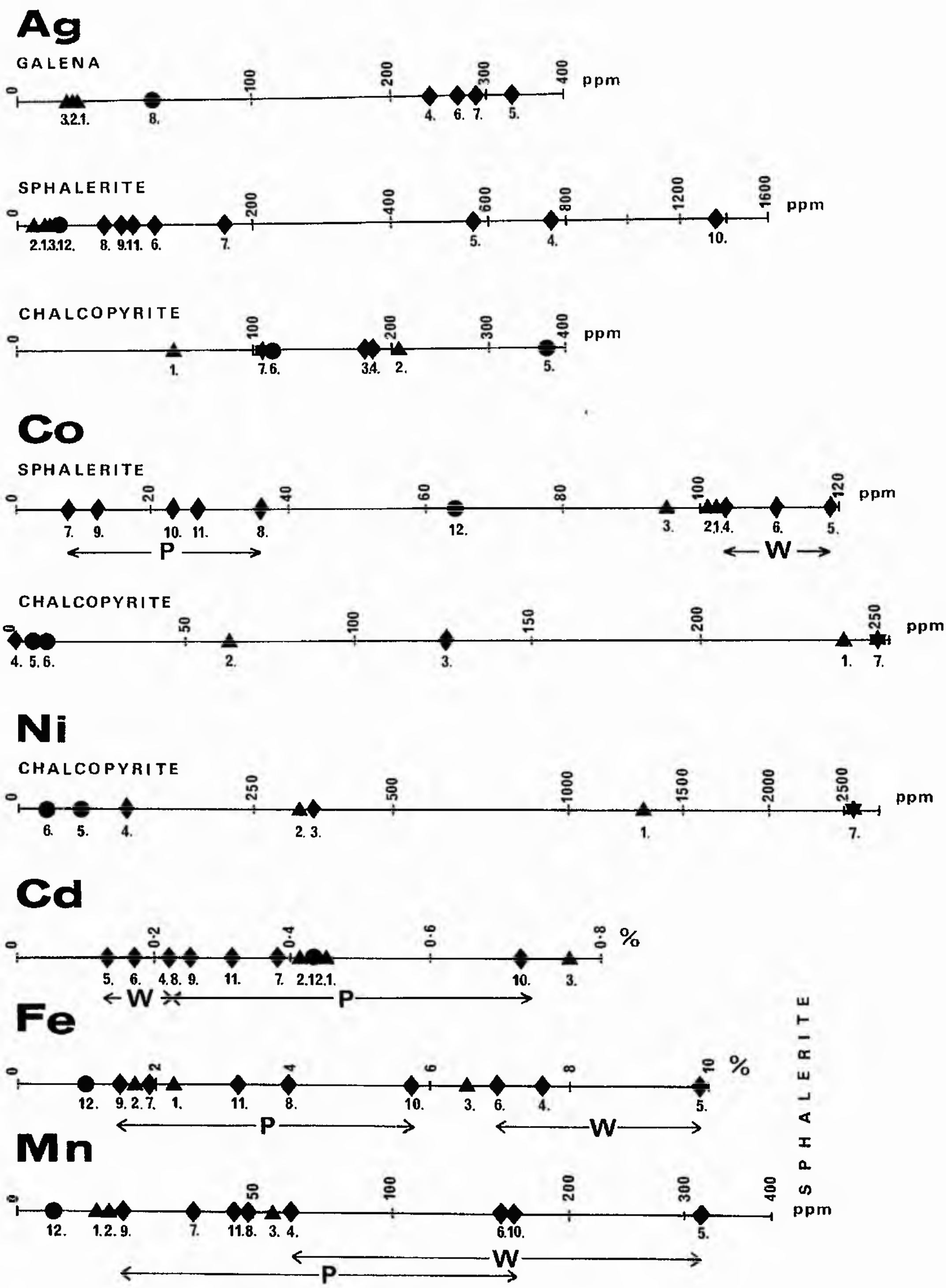
GALENA		SPHALERITE	CHALCOPYRITE
1 W.Blackcraig		1 W.Blackcraig	1 W. Blackcraig
2 E. Blackcraig		2 E. Blackcraig	2 E. Blackcraig
3 Silver Rig		3 Silver Rig	3 U. Pibble
4 Bargaly	W	4 Coldstream Burn	4 L. Pibble
5 Bargaly	W	5 Coldstream Burn	5 Drumruck
6 U. Pibble	W	6 Wood of Cree	6 W. Culcronchie
7 Dromore	P	7 Chain Burn	7 Talnotry
8 Drumruck	P	8 Meikle Bennan	
	P	9 U. Pibble	
	P	10 Dromore	
	P	11 Dromore	
		12 E. Culcronchie	

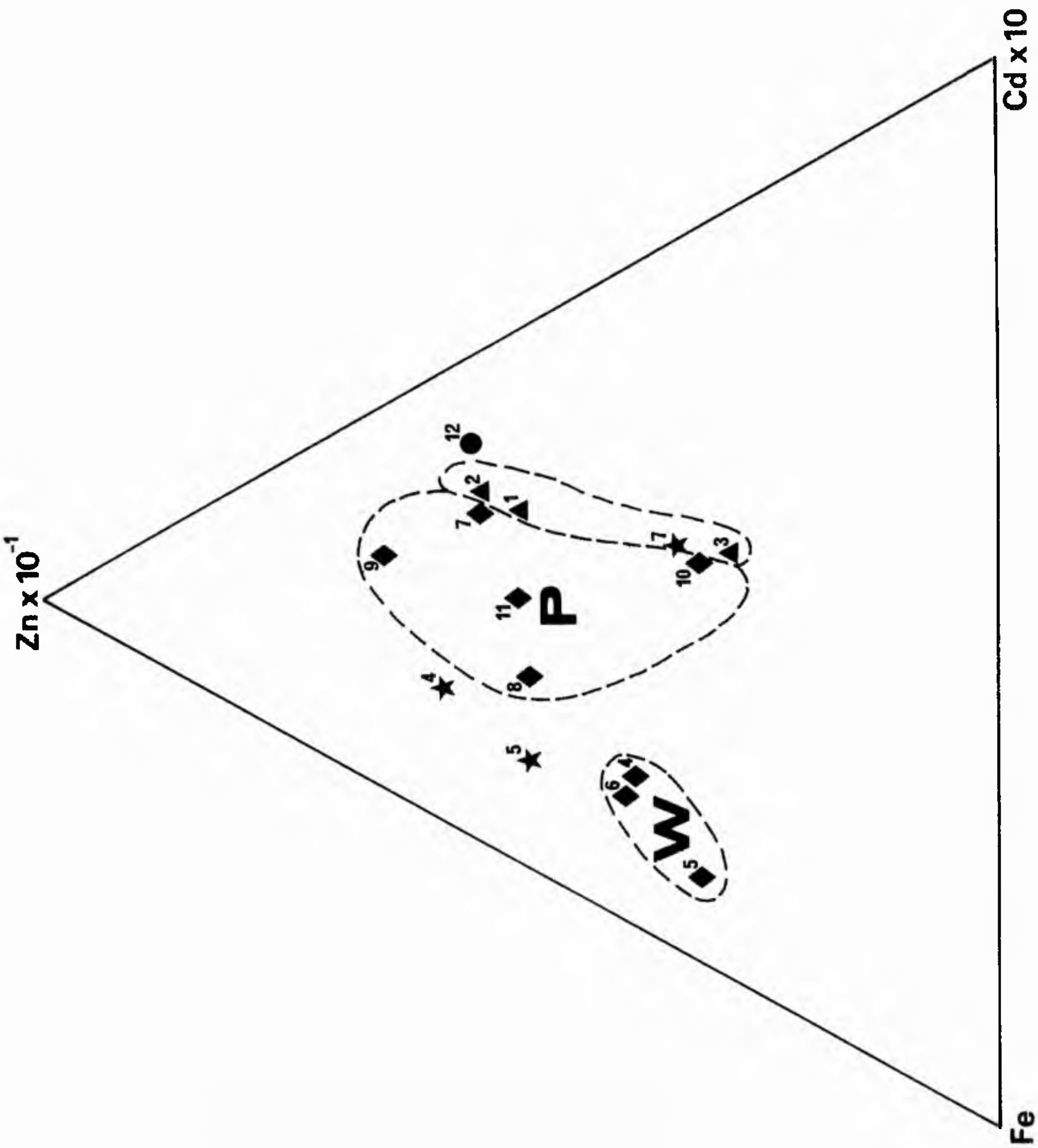
W Wood of Cree District **P** Pibble District


GALENA
3
Zn
Pb
4
5
1
2
8
Cu
7
6
Zn

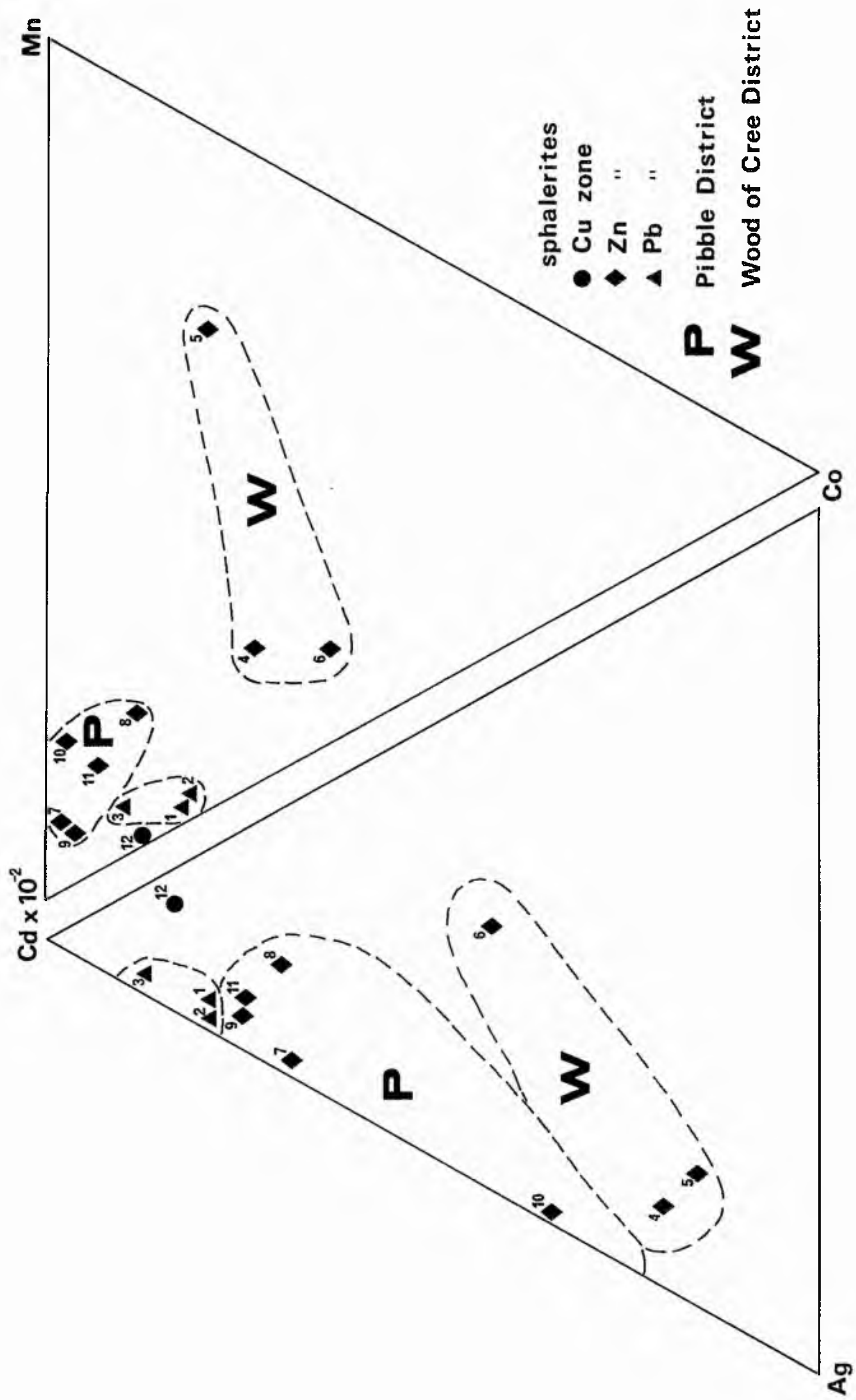

SPHALERITE
3
4
W
6
5
Zn
Pb
1
2
12
P
11
Cu
7
9
10
8
Zn


FUSION COEFFICIENT
-0·440
0·622
1·685
2·747
3·809
4·872
5·934
6·996
8·058
9·121
10·183
W. Blackcraig 1
E. Blackcraig 2
E. Culcronchie 12
Chain Burn 7
U. Pibble 9
Dromore 11
Meikle Bennan 8
Silver Rig 3
Dromore 10
Coldstream Burn 4
Wood of Cree 6
Coldstream Burn 5

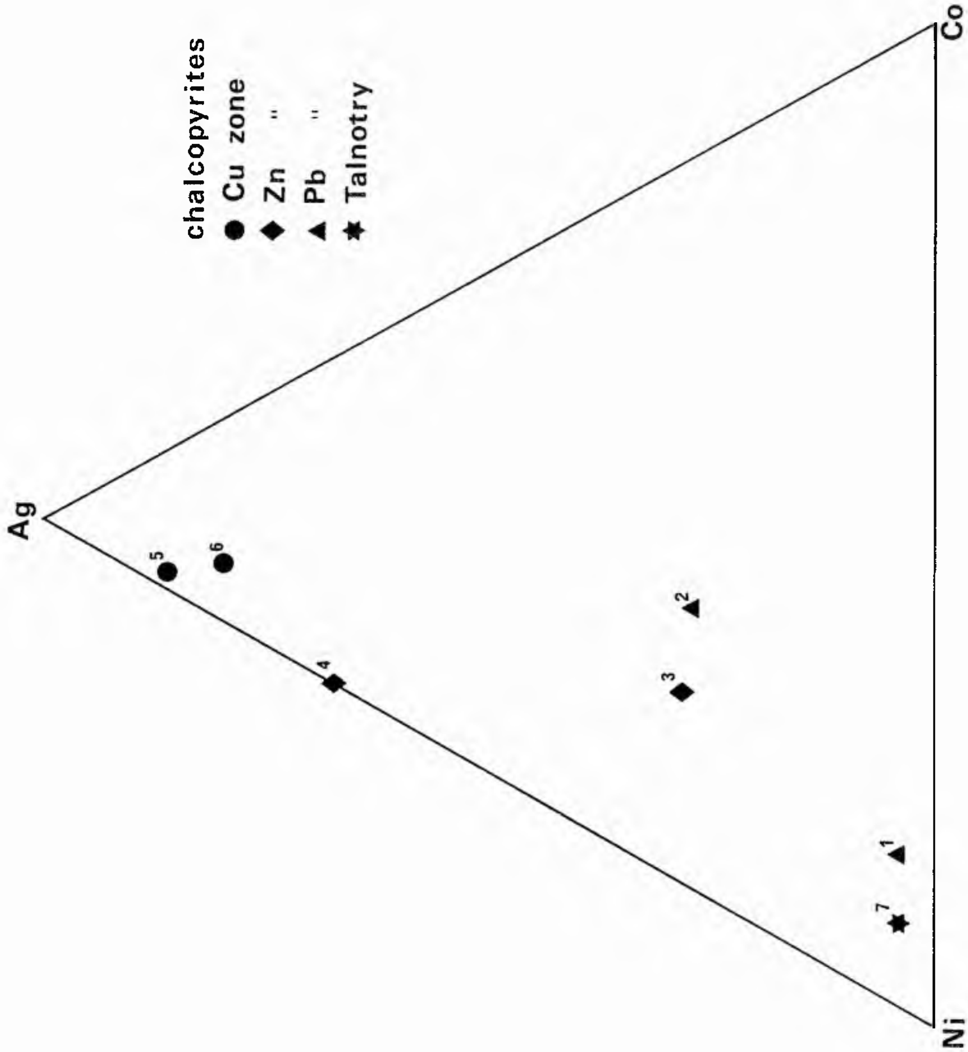

Ag
GALENA
ppm
SPHALERITE
ppm
CHALCOPYRITE
ppm
Co
SPHALERITE
ppm
P
W
CHALCOPYRITE
ppm
Ni
CHALCOPYRITE
ppm
Cd
%
W
P
Fe
%
P
W
Mn
ppm
W
P
SPHALERITE



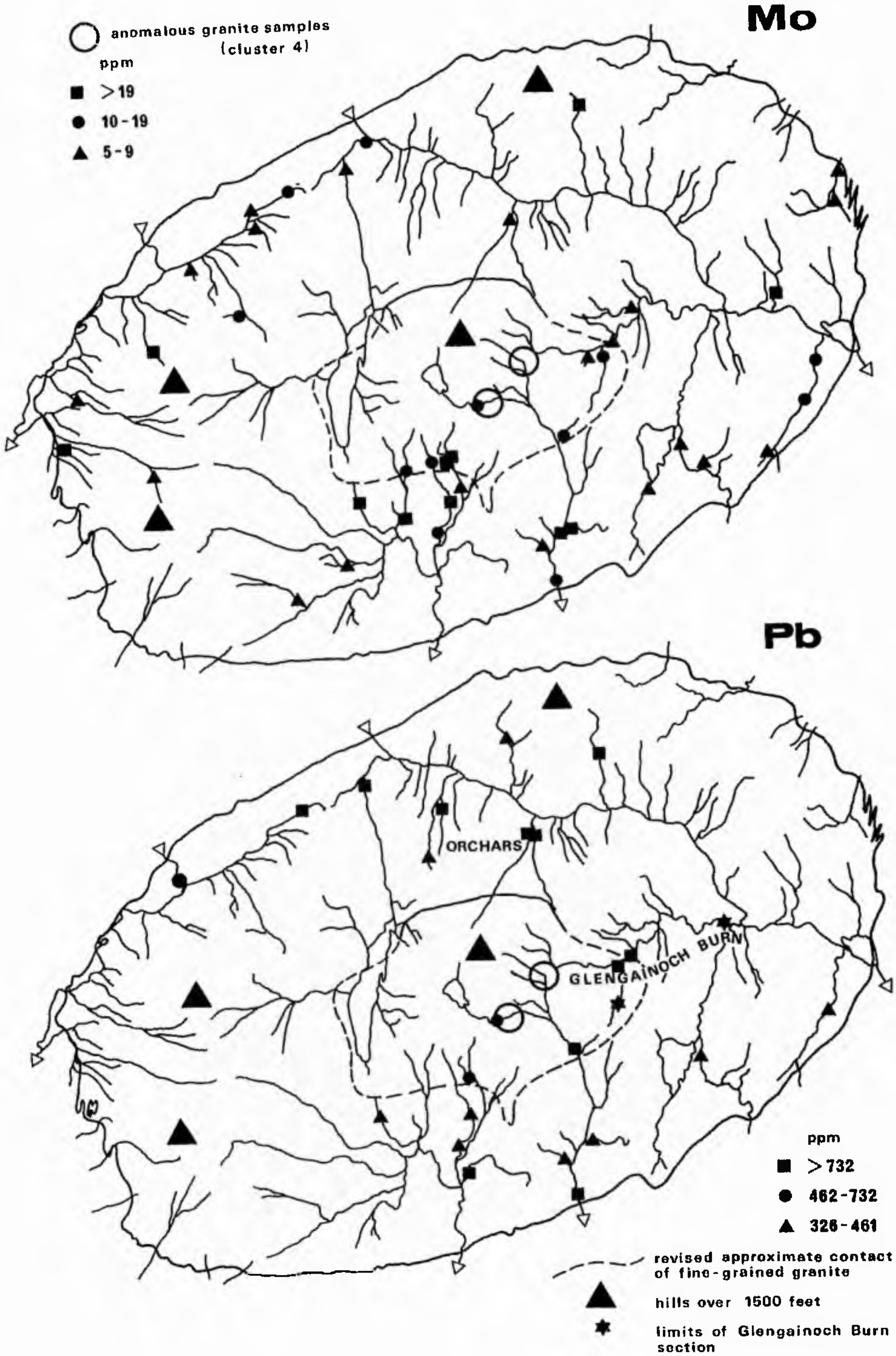
Zn x 10^{-1}
Cd x 10
Fe
P
W

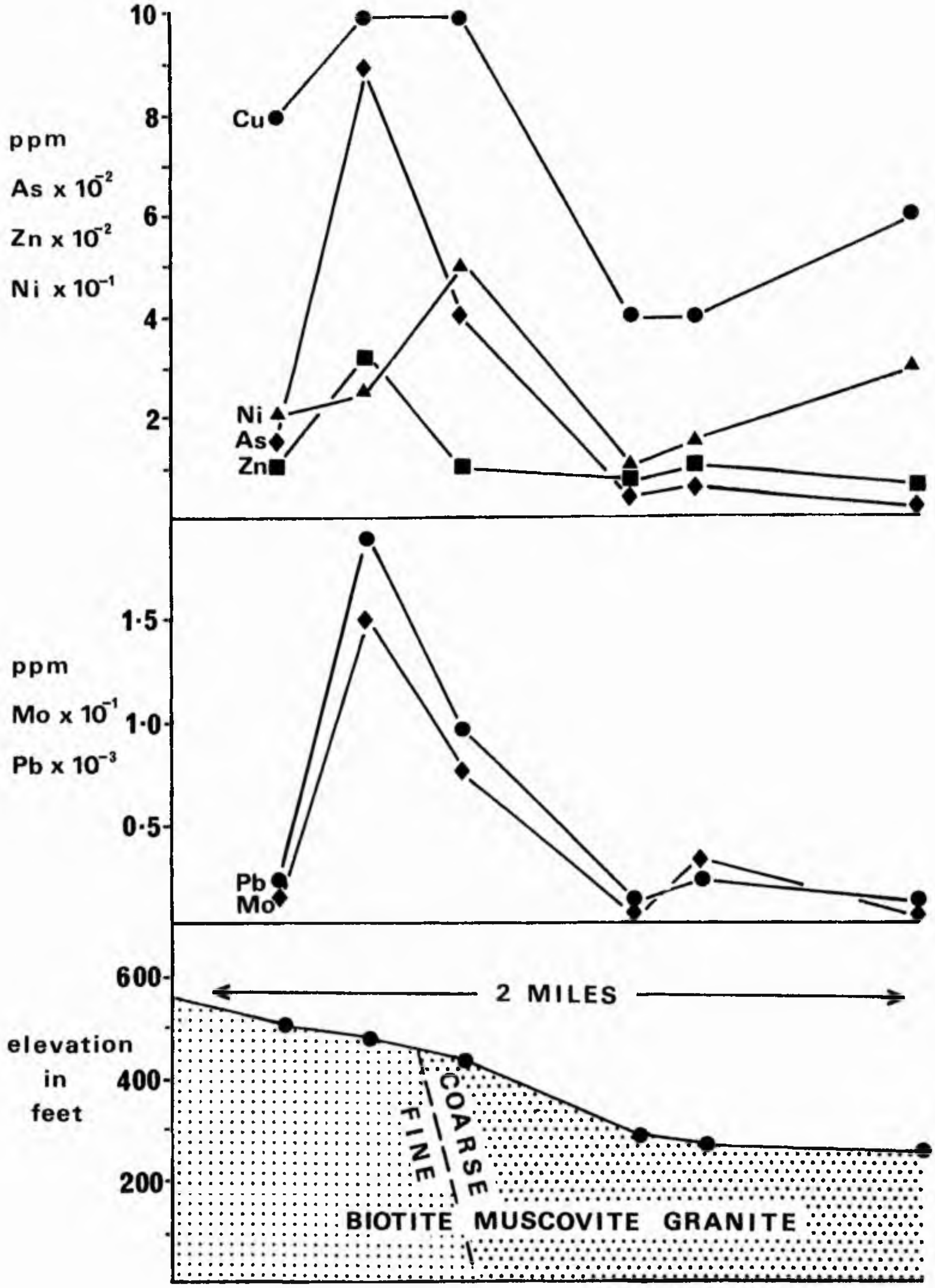


Mn
Cd x 10^{-2}
Co
Ag
P
W
sphalerites
Cu zone
Zn "
Pb "
P Pibble District
W Wood of Cree District

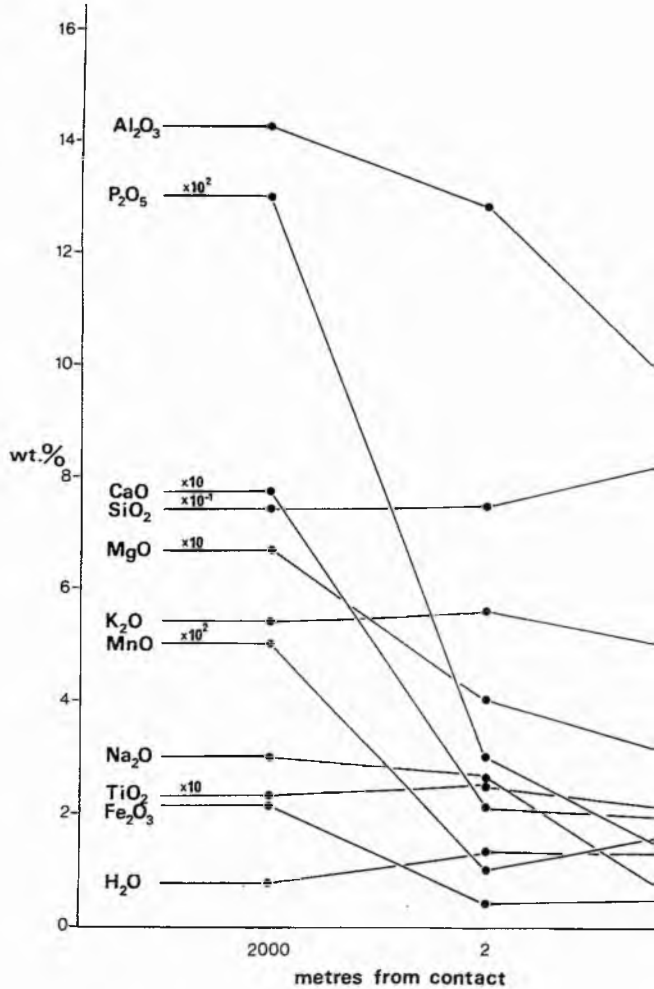

Ag
Ni
Co
chalcopyrites
Cu zone
Zn "
Pb "
Talnotry
1
2
3
4
5
6
7

FIGURES. 105 - 109.

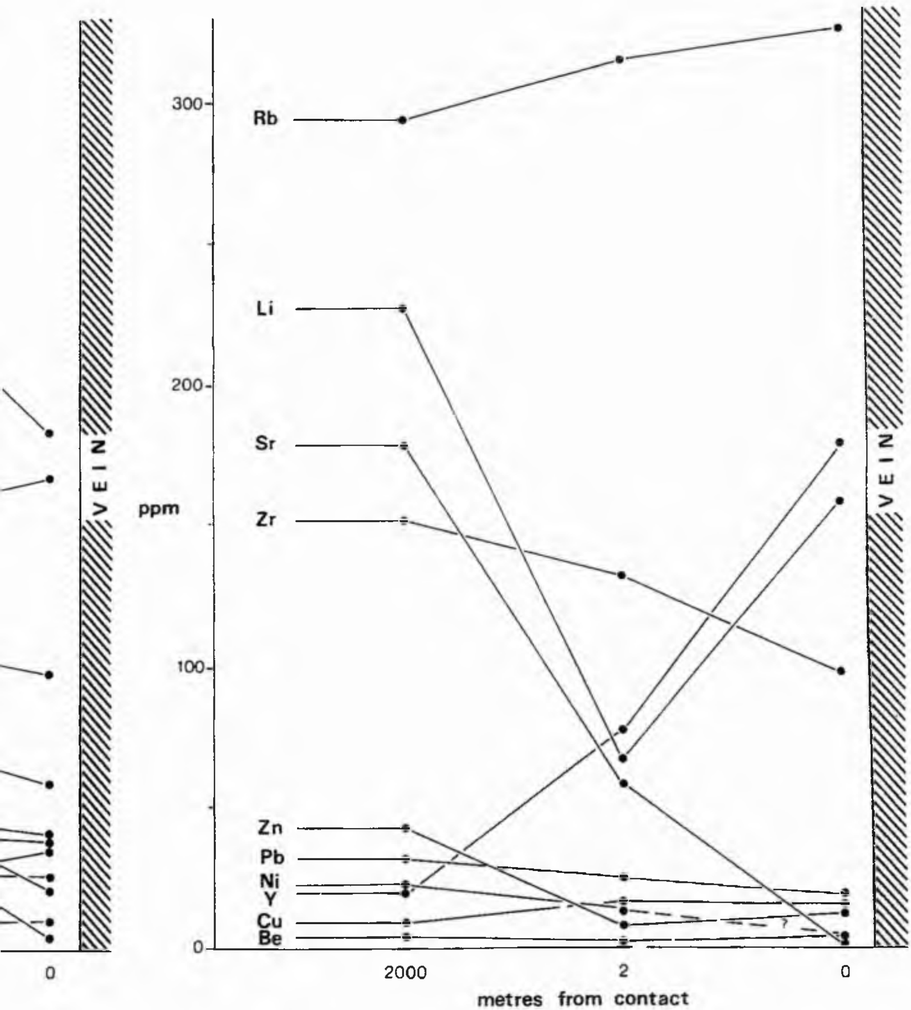

Mo
anomalous granite samples (cluster 4)
ppm
>19
10 - 19
5 - 9
Pb
ORCHARS
GLENGAINOCH BURN
ppm
>732
462 - 732
326 - 461
revised approximate contact of fine-grained granite
hills over 1500 feet
limits of Glengainoch Burn section



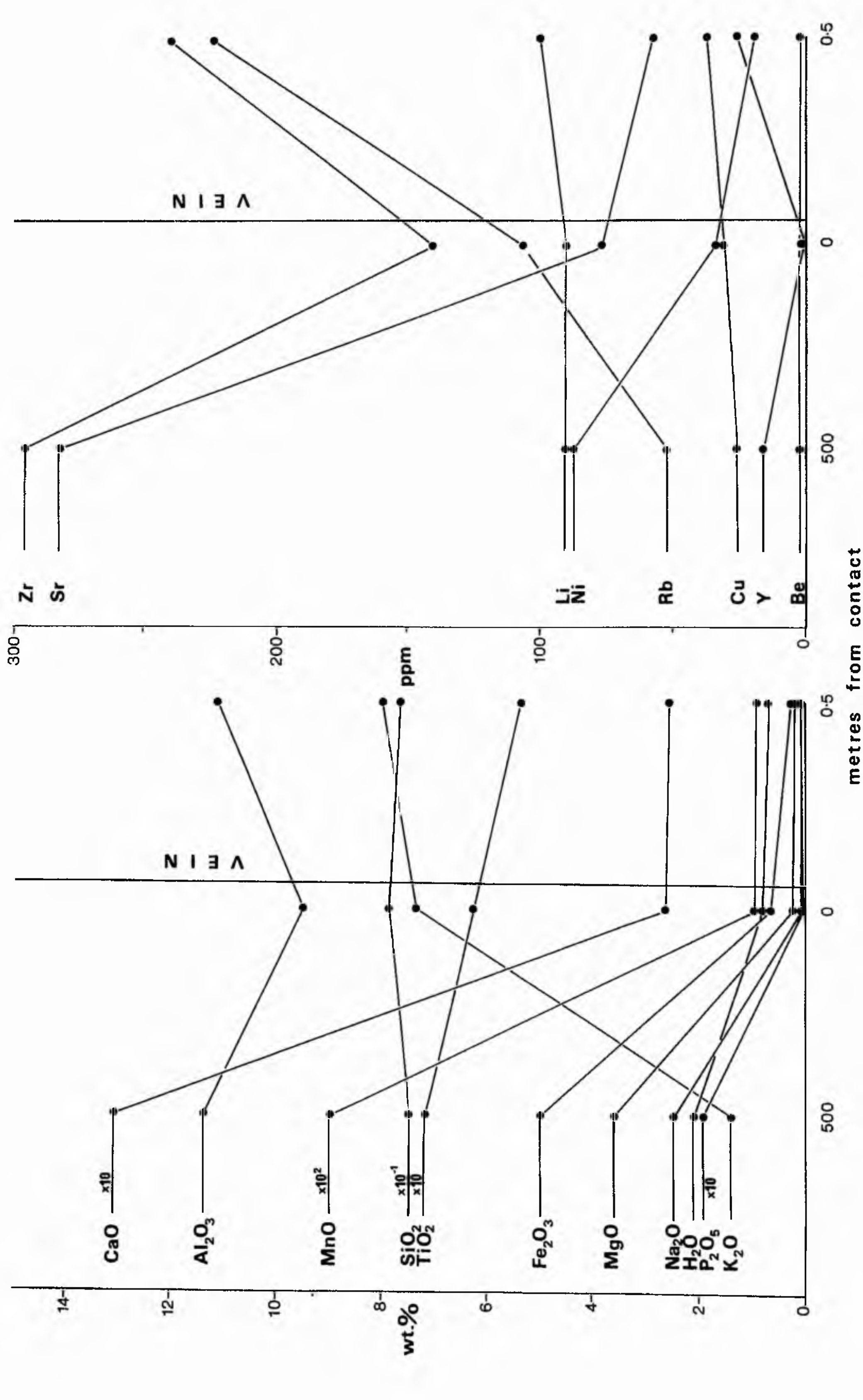
10
8
6
4
2
ppm
As x 10⁻²
Zn x 10⁻²
Ni x 10⁻¹
Cu
Ni
As
Zn
1·5
1·0
0·5
ppm
Mo x 10⁻¹
Pb x 10⁻³
Pb
Mo
600
400
200
elevation
in
feet
2 MILES
FINE
COARSE
BIOTITE MUSCOVITE GRANITE



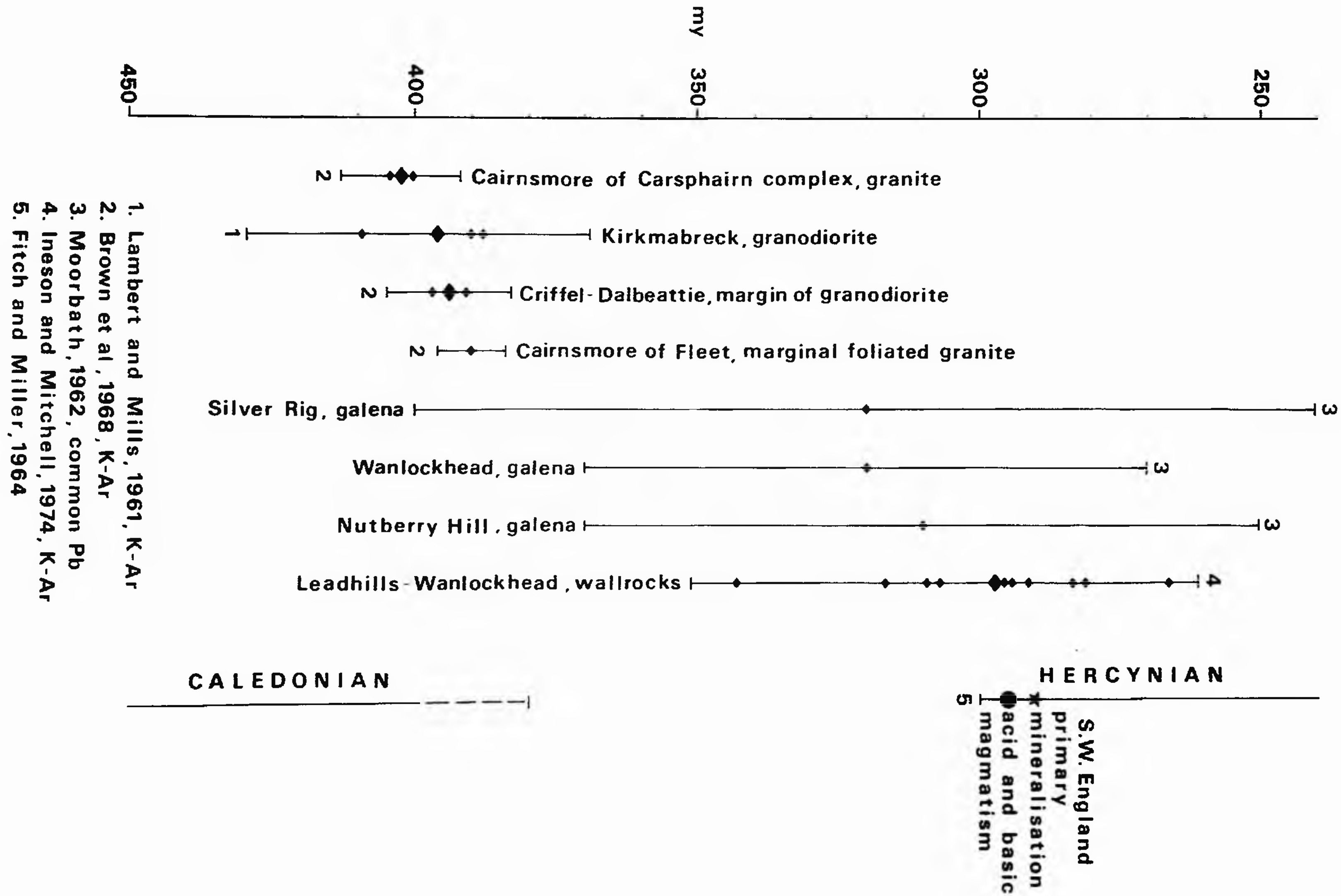
wt.%
16
14
12
10
8
6
4
2
0
Al2O3
P2O5 x10²
CaO x10
SiO2 x10⁻¹
MgO x10
K2O
MnO x10²
Na2O
TiO2 x10
Fe2O3
H2O
2000
2
metres from contact



VEIN
300
200
100
0
ppm
Rb
Li
Sr
Zr
Zn
Pb
Ni
Y
Cu
Be
?
VEIN
0
2000
2
0
metres from contact



wt.%
ppm
CaO x10
Al2O3
MnO x10²
SiO2 x10⁻¹
TiO2 x10
Fe2O3
MgO
Na2O
H2O
P2O5 x10
K2O
Zr
Sr
Li
Ni
Rb
Cu
Y
Be
VEIN
VEIN
metres from contact


my
450
400
350
300
250
Cairnsmore of Carsphairn complex, granite
Kirkmabreck, granodiorite
Criffel - Dalbeattie, margin of granodiorite
Cairnsmore of Fleet, marginal foliated granite
Silver Rig, galena
Wanlockhead, galena
Nutberry Hill, galena
Leadhills - Wanlockhead, wallrocks
1. Lambert and Mills, 1961, K-Ar
2. Brown et al, 1968, K-Ar
3. Moorbath, 1962, common Pb
4. Ineson and Mitchell, 1974, K-Ar
5. Fitch and Miller, 1964
CALEDONIAN
HERCYNIAN
S.W. England
primary
mineralisation
acid and basic
magmatism

PLATES

Arrow heads indicate scale of 0.5 mm on the photomicrographs; other scales are given in the captions.

X.p.l = cross polarised light.

p.p.l = plane polarised light.

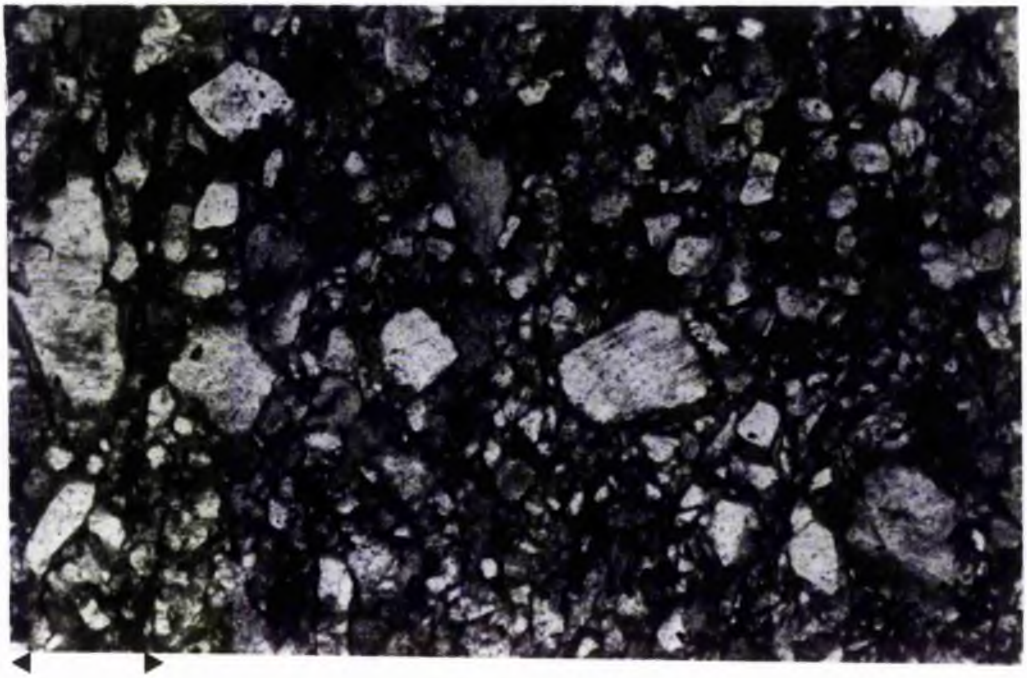
PLATES 1 - 4.

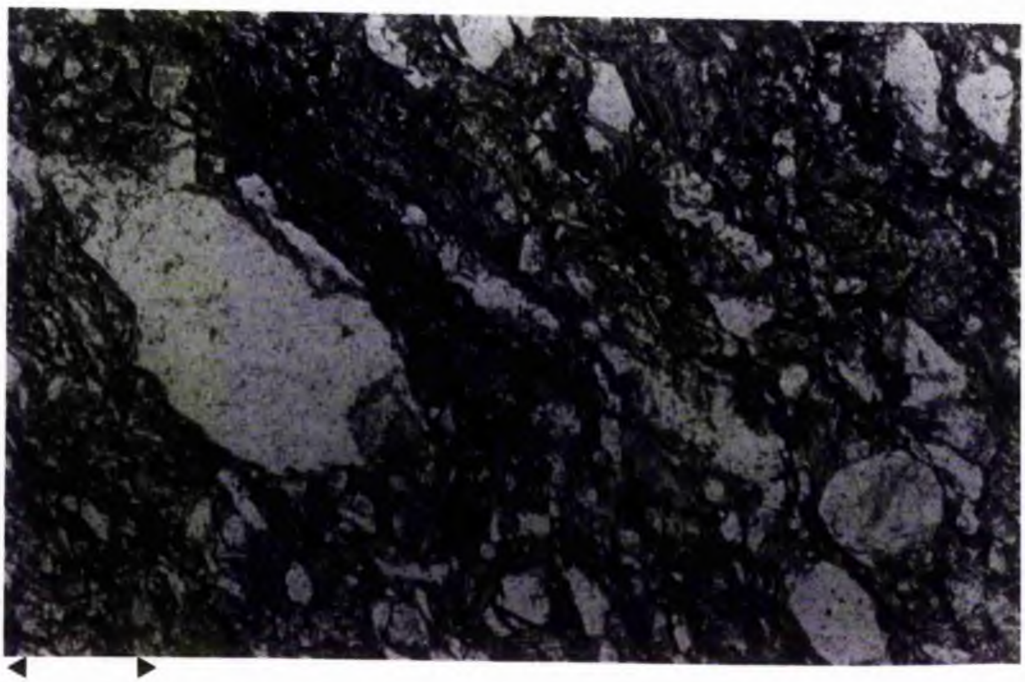
PLATE 1. Lithic greywackes: top, 74/H. 66-68 Craignell Formation; bottom, 74/H. 54-60 Knockeans Formation. (p.p.l., x 40).

PLATE 2. Basic greywackes: top, 74/H. 50-74 Craignell Formation; bottom, 74/H. 52-76 Craignell Formation. (p.p.l., x 40).

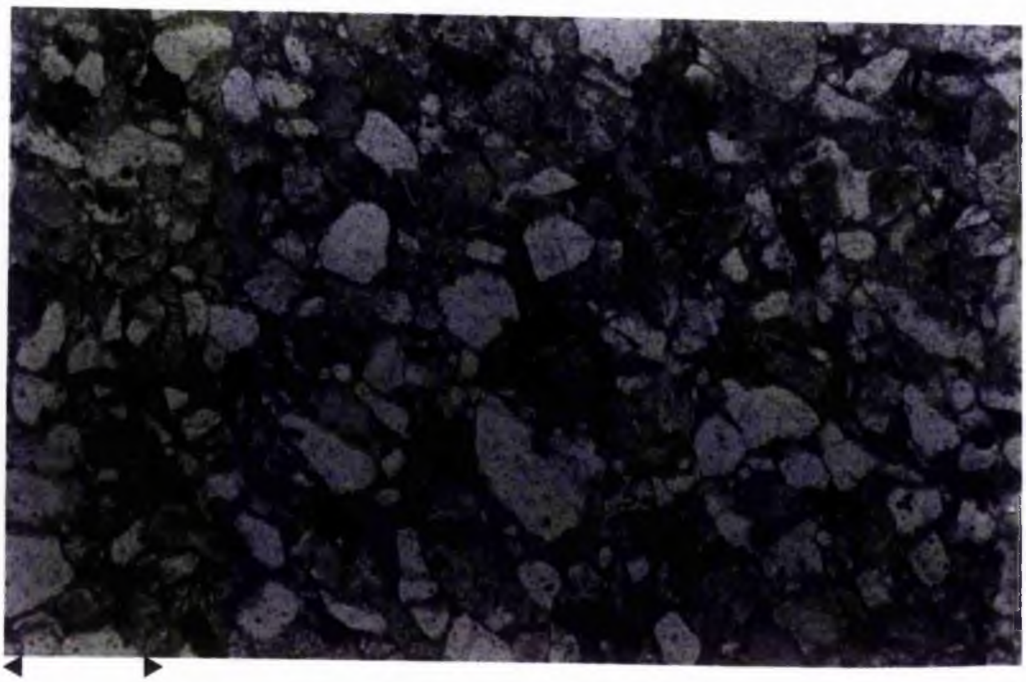
PLATE 3. Feldspathic greywacke: top, 74/H. 66-68 Craignell Formation (p.p.l.); bottom, 74/H. 66-68 Craignell Formation (X. p.l., x 40).

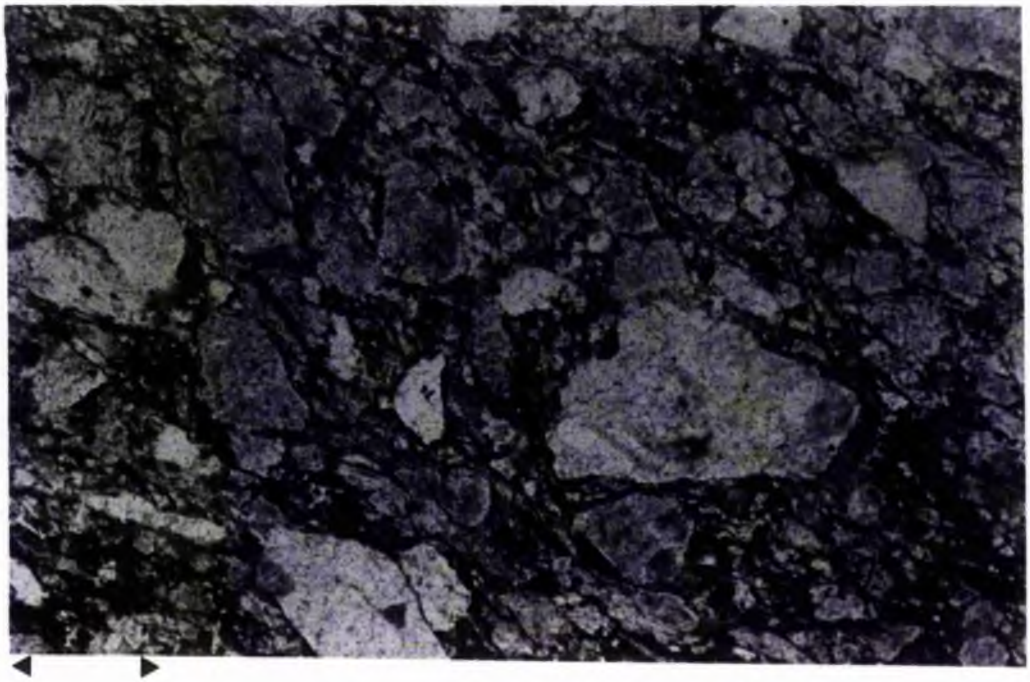
PLATE 4. Silicic greywackes: top, 74/H. 61-63 Craignell Formation; bottom, 74/H. 50-58 Knockeans Formation (p.p.l., x 40).

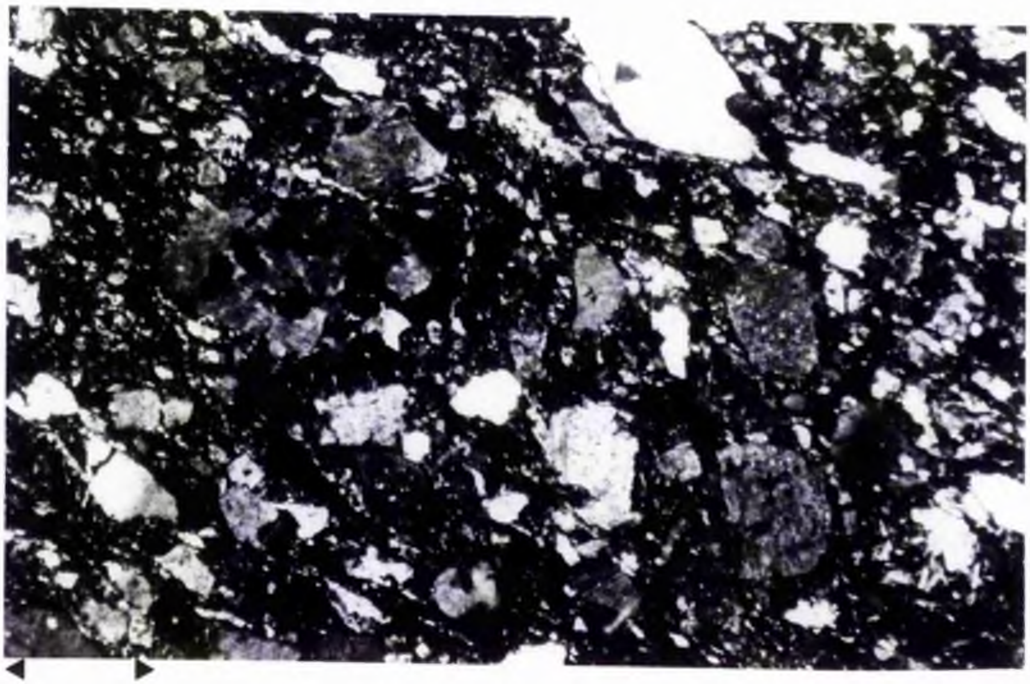




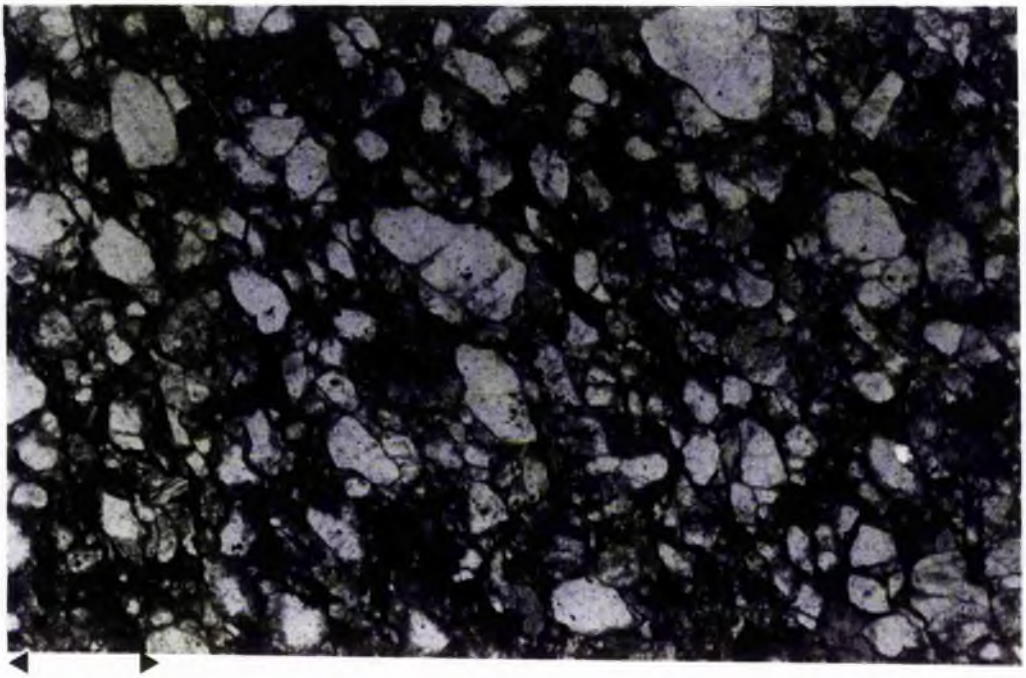
1

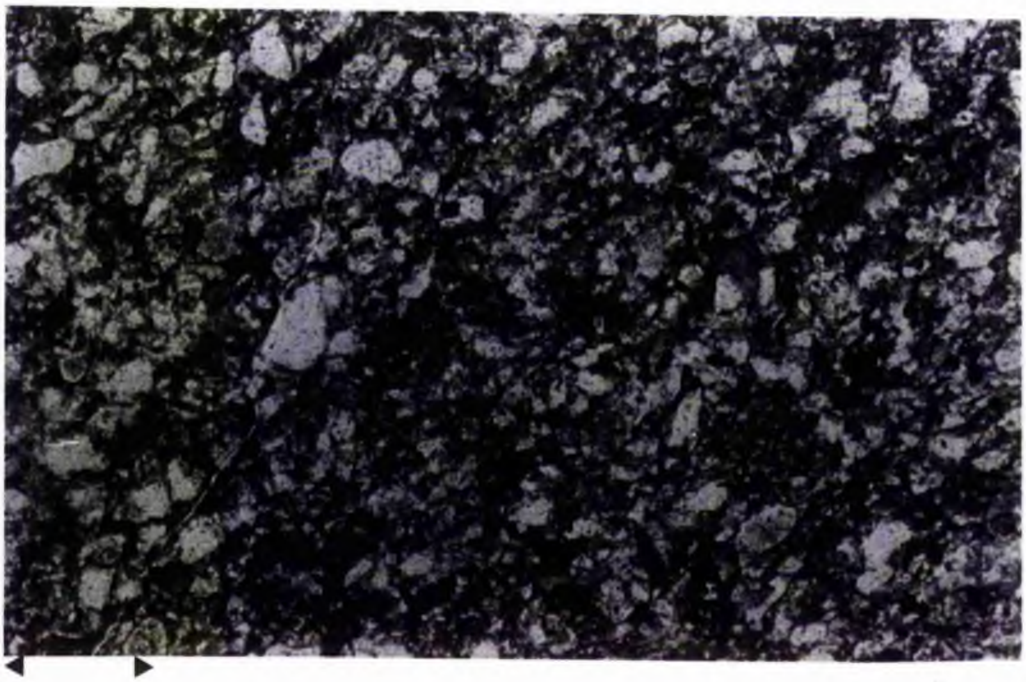






3





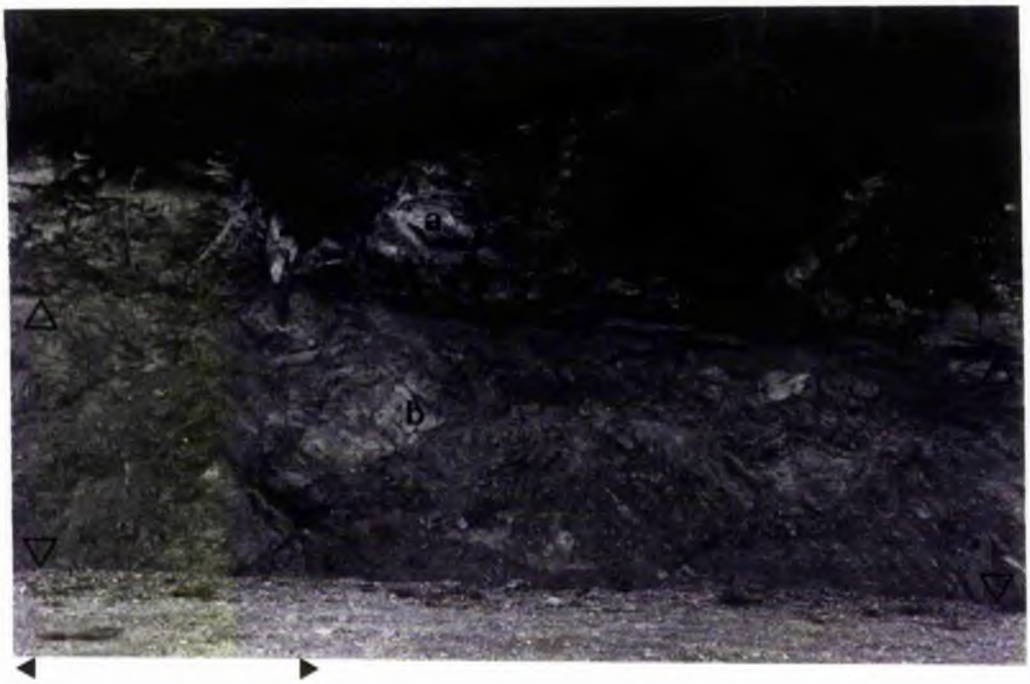
PLATES 5 - 8.

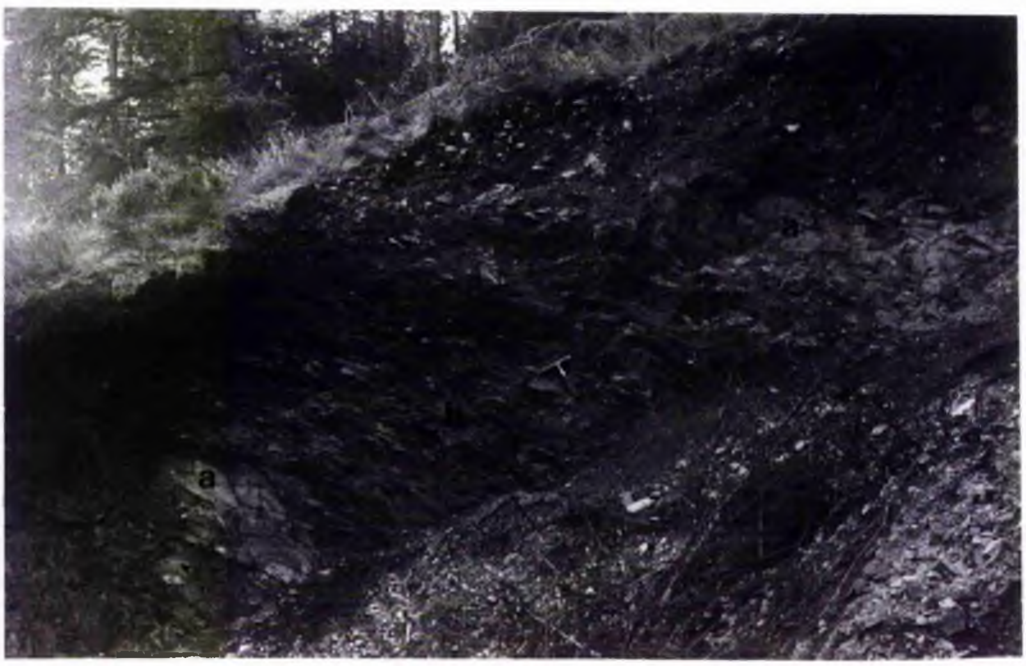
PLATE 5. Top, locality 872, grey mudstones (a) thrust over crushed grey shale and greywacke (b). Fissile black shale (c) occurs along the fault plane. Brecciation zone of the Talnotry Thrust between arrow heads. Scale = 2 m. Bottom, locality 868, grey mudstone (a) and black Hartfell lithology shale (b) sequence exposed in a basal Schuppe of the Talnotry thrust zone.

PLATE 6. Top, locality 872, contorted grey shales (a) thrust over a crushed band of greywacke (b). Brecciation zone of the Talnotry Thrust, Talnotry. Scale = 2 m. Bottom, locality 868, crushed black shale (b) along a minor thrust plane within grey mudstones (a) exposed above the Talnotry Thrust.

PLATE 7. Top, locality 840, reverse faulting (f) in Craignell greywackes below the Talnotry Thrust, Craigdistant Hill. Scale = 1 m. Bottom, locality 867, fault-bounded (f) wedge of greywacke (g) within black mudstones (m); fault zone of the Talnotry Thrust, Talnotry.

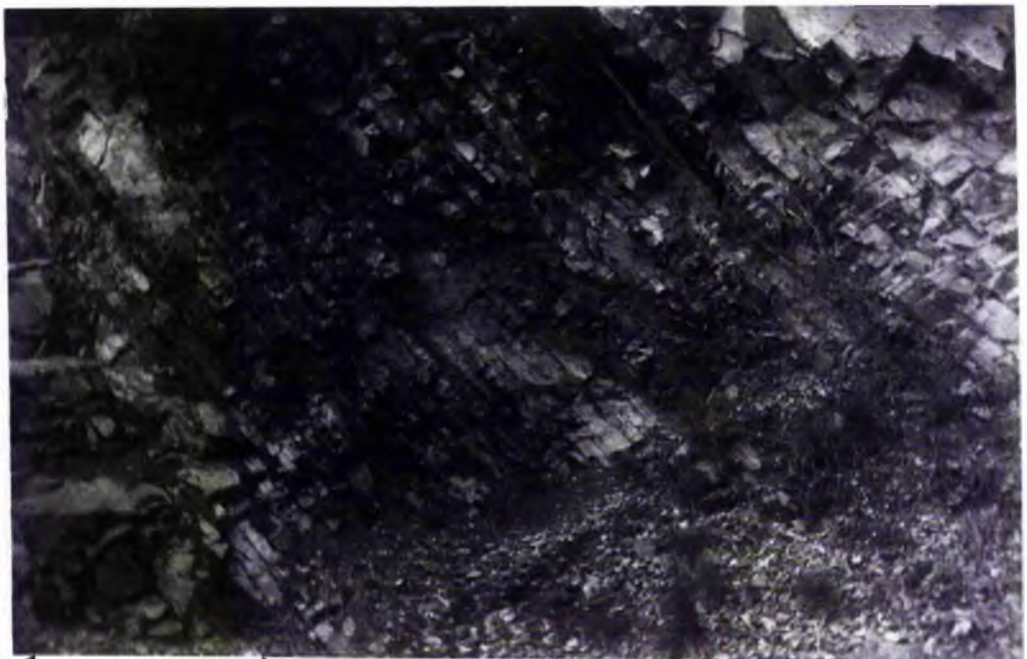
PLATE 8. Top, fault-bounded arch in Craignell greywackes below the Talnotry Thrust, lower waterfall, Grey Mare's Tail Burn, Talnotry. Scale = 2 m. Bottom, locality 874, black mudstones (m) thrust over greywacke (g). Between the faults (f) are slices of crushed black (m) and green (c) chloritic mudstones. Upper Waterfall, Grey Mare's Tail Burn, Talnotry.

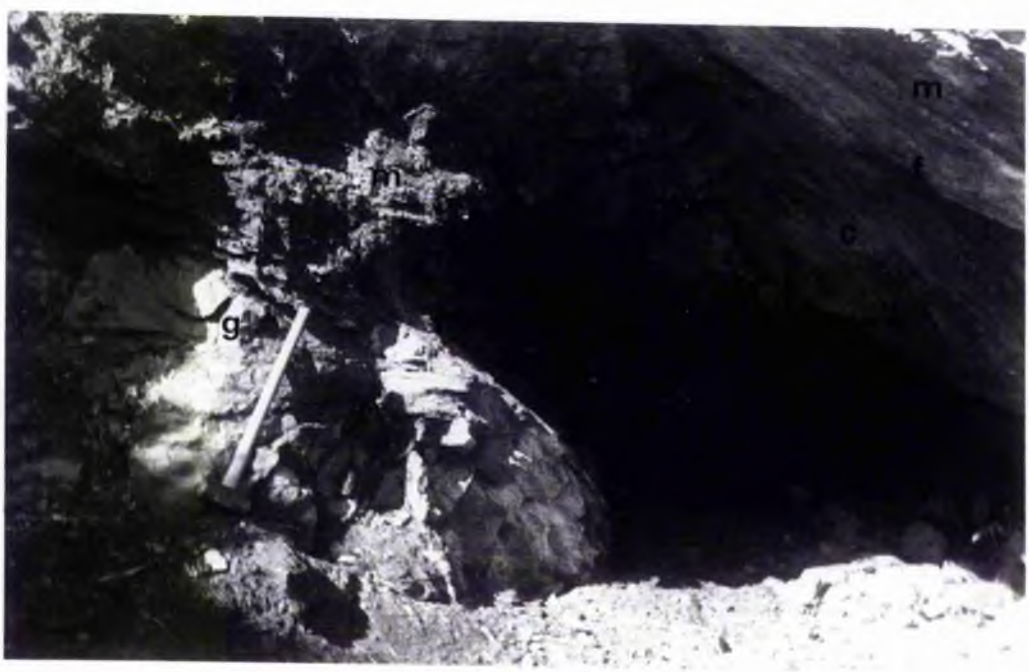

a
b


a


a
b


a
b
a




m
m
f
c
g

PLATES 9 - 11.

PLATE 9. Top, locality 085, Culcronchie upper veins. Upper (u) and middle (m) brecciation zones of the Culcronchie Thrust (reverse fault) in black mudstones. Brecciation zones (limits defined by arrow heads) dip 60^{o}N, bounding slices of greywacke hornfels (b). Looking east. Scale = 5 m.
Bottom, locality 629, low amplitude F_{2a} flexures in Craignell greywackes, Pibble Hill.

PLATE 10. Top, locality 1169, the Pool Ness Thrust (reverse fault) at Pool Ness, Big Water of Fleet. Black laminated mudstones of Birkhill lithology (m) pass upwards conformably into Craignell arenites (g) and are faulted (f) against black Birkhill lithology mudstones (m_1) to the south and Craignell arenites (g_1) to the north. Looking east. Scale = 5 m.
Bottom, locality 1169, stratigraphical contact between black mudstones of Birkhill affinity and Craignell greywacke. Looking west. Scale = 0.5 m.

PLATE 11. Top, locality 1169, stratigraphical contact between (Birkhill) mudstones (m) and Craignell greywacke (g), and faulted (f) contact with black mudstones (m_1) of Birkhill lithology. Pool Ness, Big Water of Fleet. Looking east. Scale = 2.5 m.
Bottom, locality 1169, Craignell greywackes (g_1) in faulted contact (f) with Birkhill lithology mudstones (m). Looking east. Scale = 2.5 m.


u
g
m


g

m
g

g1
m

PLATES 12 - 16.

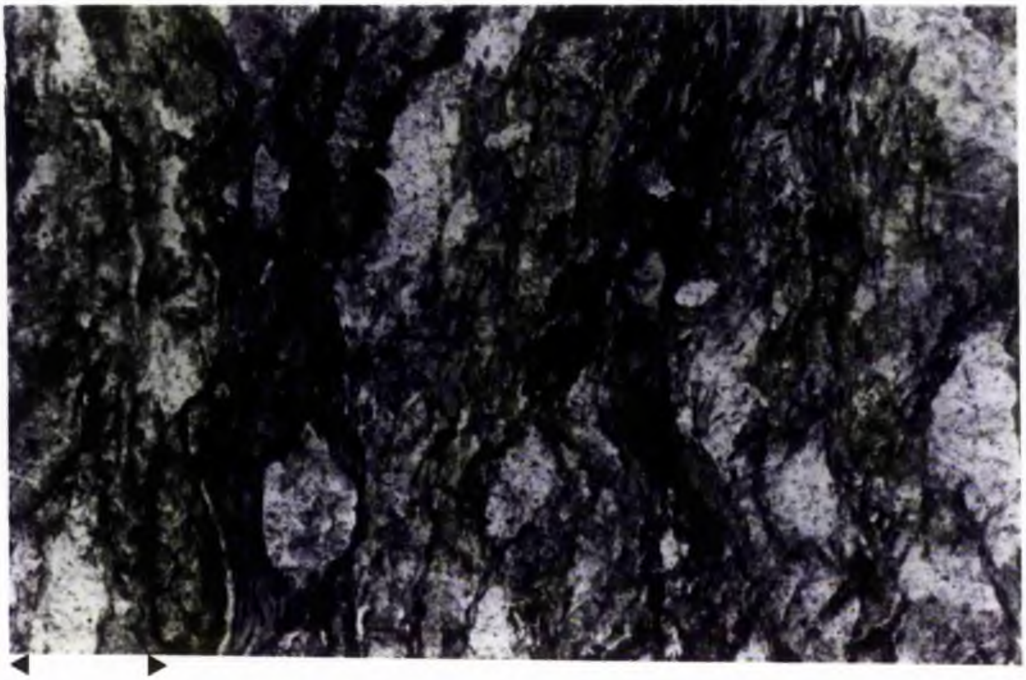
PLATE 12. Top, albite-epidote hornfels facies, chlorite-biotite zone hornfels 74/H. 45-67, aggregates of chlorite arrowed; bottom, hornblende hornfels facies, biotite zone, low grade pelitic hornfels 74/H. 46-70, sedimentary lamination horizontal, incipient strain-slip cleavage top right-bottom left (p.p.1, x 40).

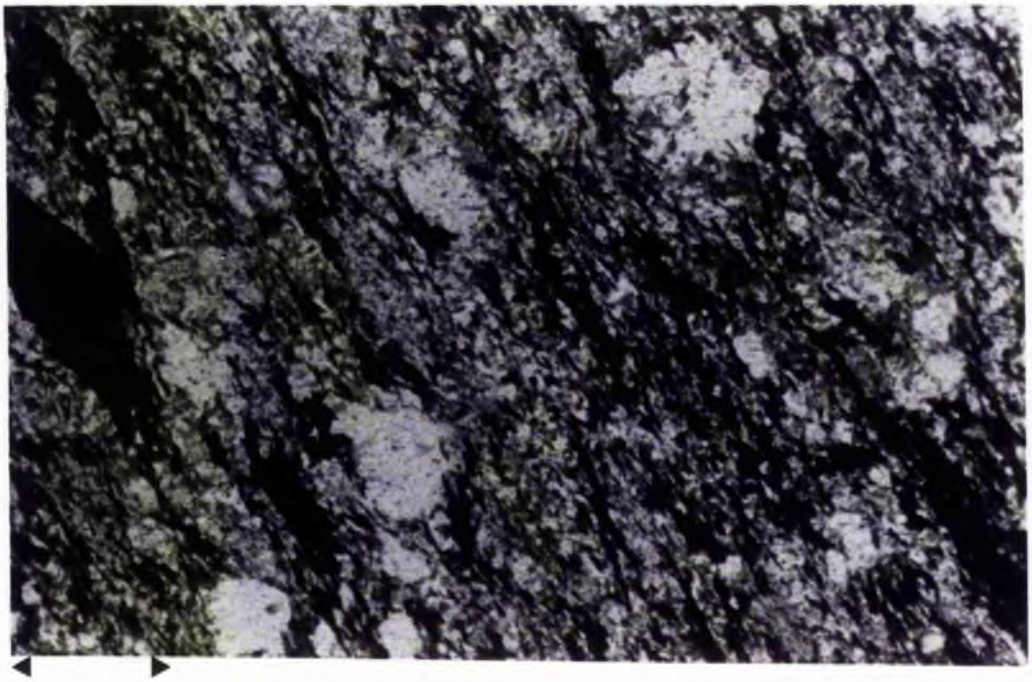
PLATE 13. Hornblende hornfels facies: top, biotite zone hornfels 74/H. 47-69, containing pale xenoblastic aggregates of cordierite crystals and dark orientated crystals of biotite; bottom, biotite zone hornfels 74/H. 59-77, containing dark crystals of biotite (p.p.1., x 40).

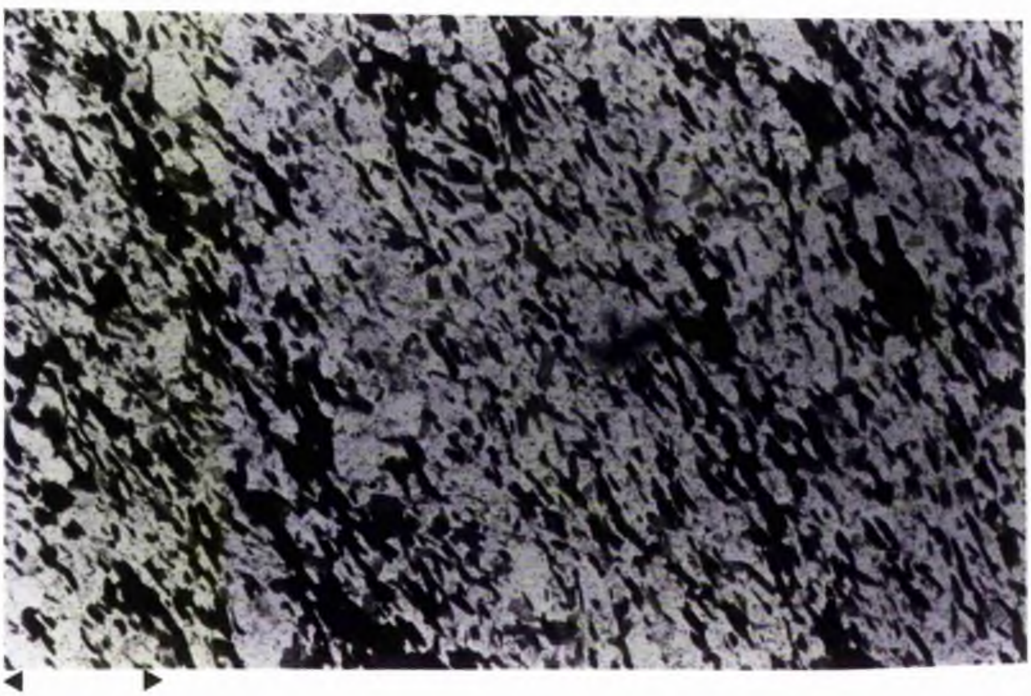
PLATE 14. Hornblende hornfels facies: top, hornblende-biotite zone hornfels 74/46-64, containing biotite (dark) and ferroactinolite/hornblende amphibole (lighter grey); bottom, hornblende-biotite zone hornfels 74/50-64 containing ferroactinolite/hornblende amphibole (dark), (p.p.1., x 40).

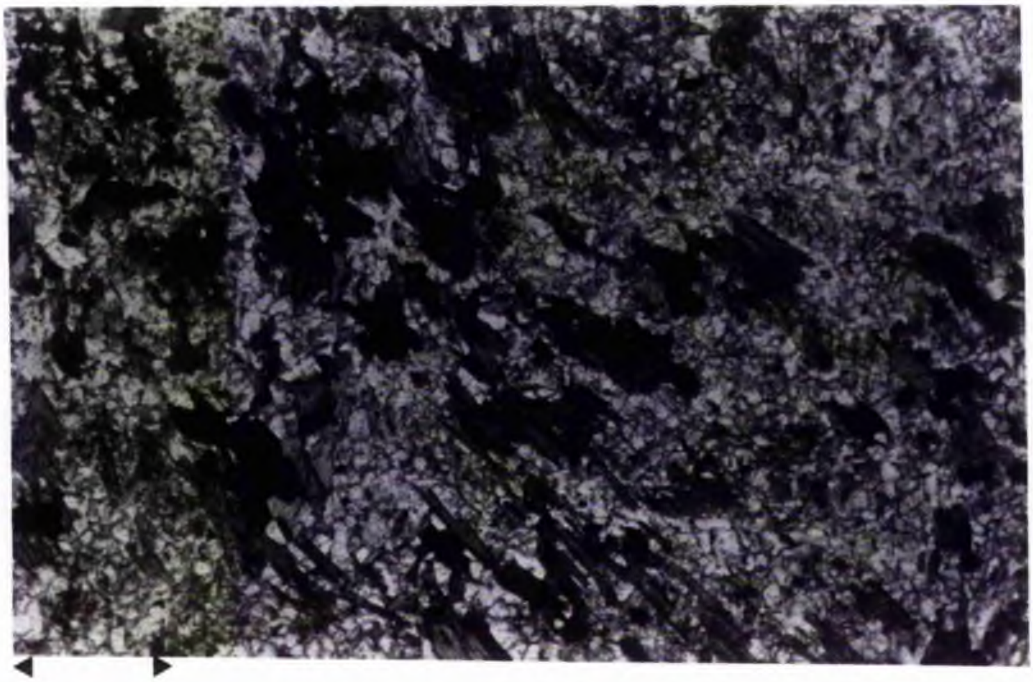
PLATE 15. Hornblende hornfels facies: top, hornblende-biotite zone hornfels 74/48-66, pelitic hornfels containing biotite (dark) and almandine garnet (medium grey, high relief); bottom, biotite-hornblende zone hornfels 74/49-63, transformed ultrabasic intrusive producing tremolite-talc hornfels (Clanery Hill), (p.p.1., x 40).

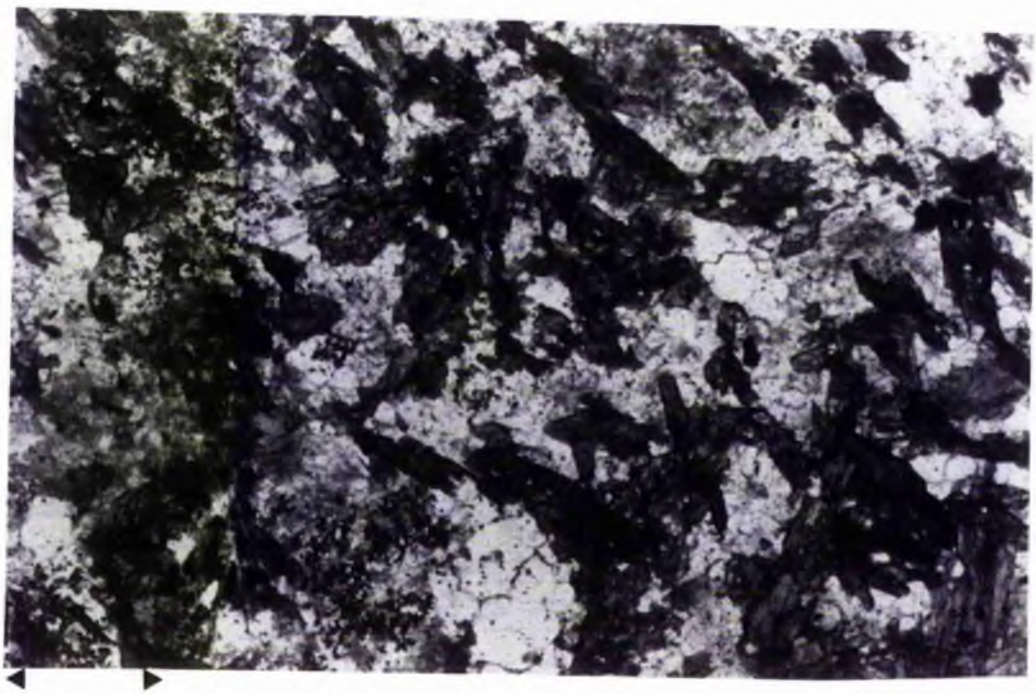
PLATE 16. Hornblende hornfels facies: top, clinozoisite-biotite hornfels 74/H. 59-65, clinozoisite is grey mineral with high relief (p.p.1., x 100); bottom, uralite-hornfels 74/H. 50-60, uralite in dark grey radiating aggregates (p.p.1., x 40).

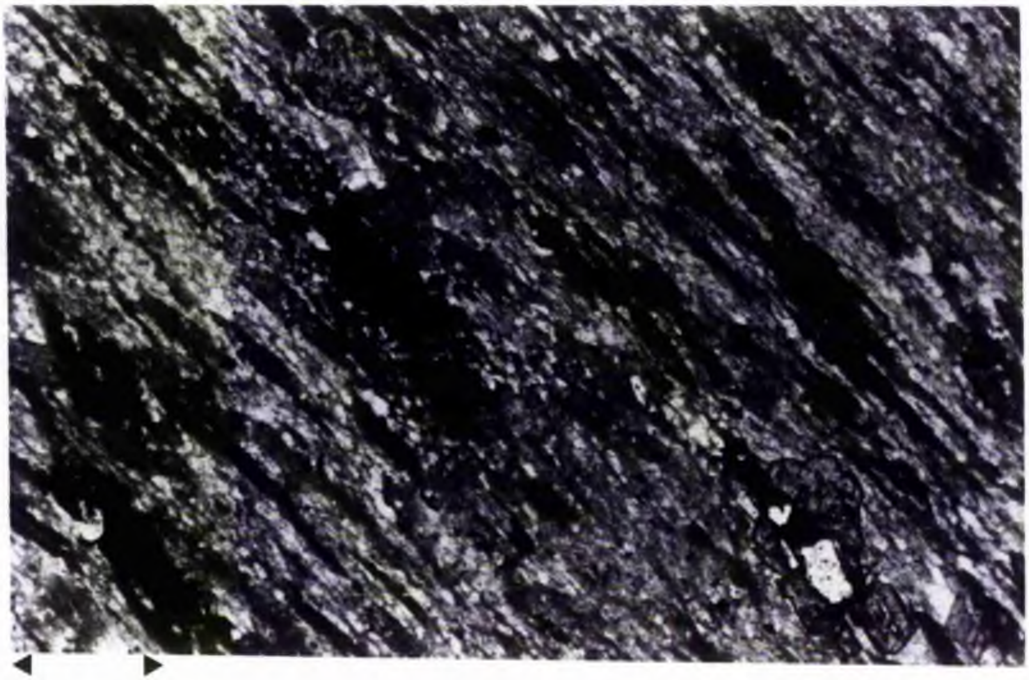


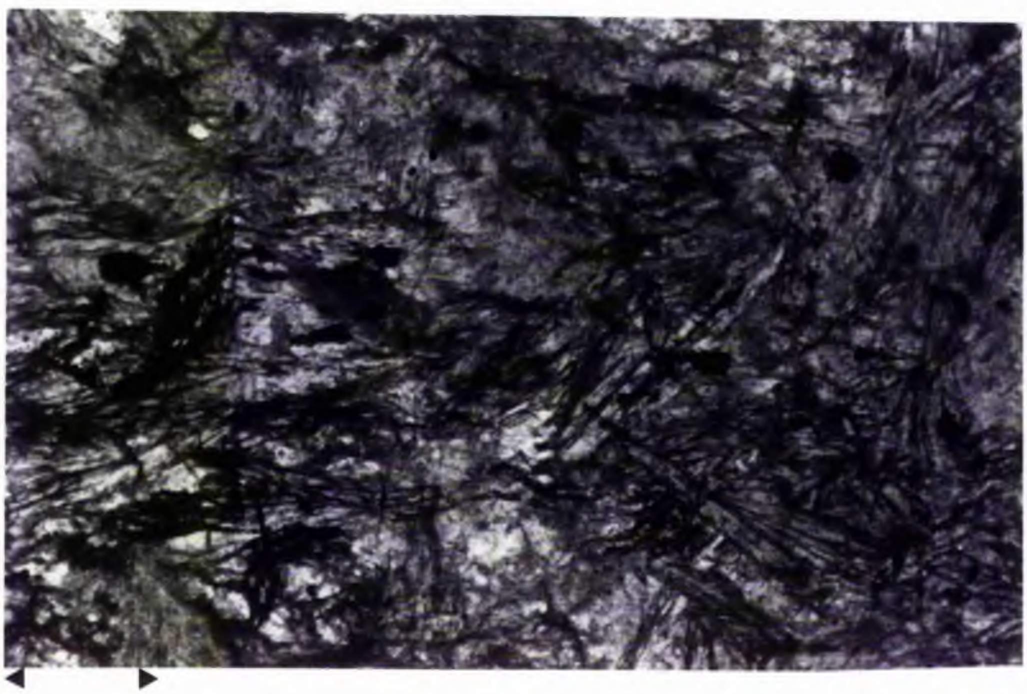


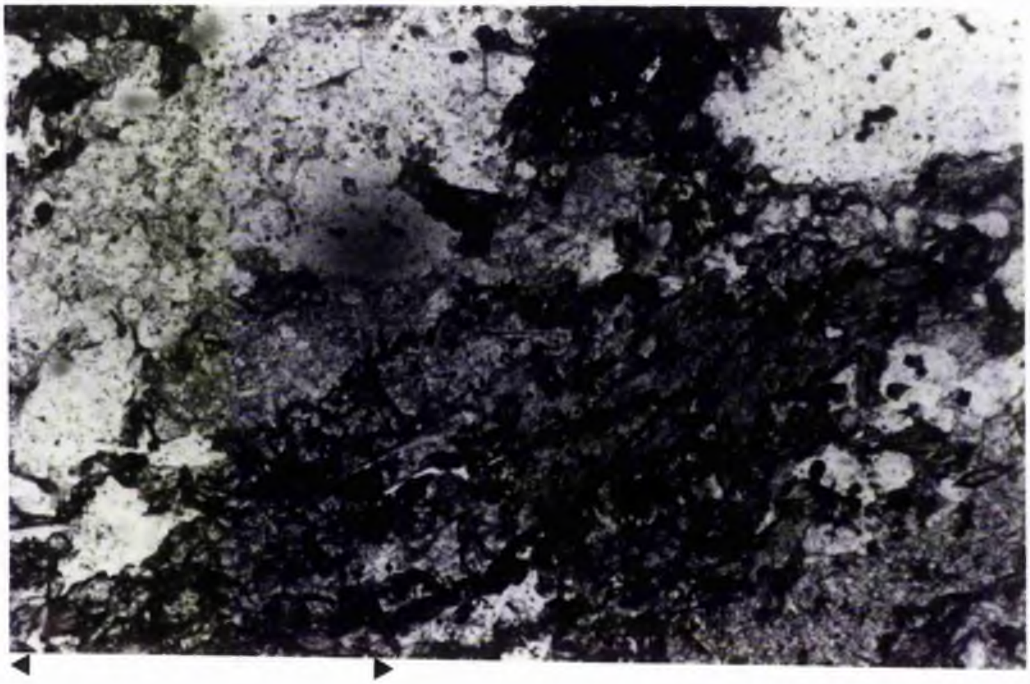


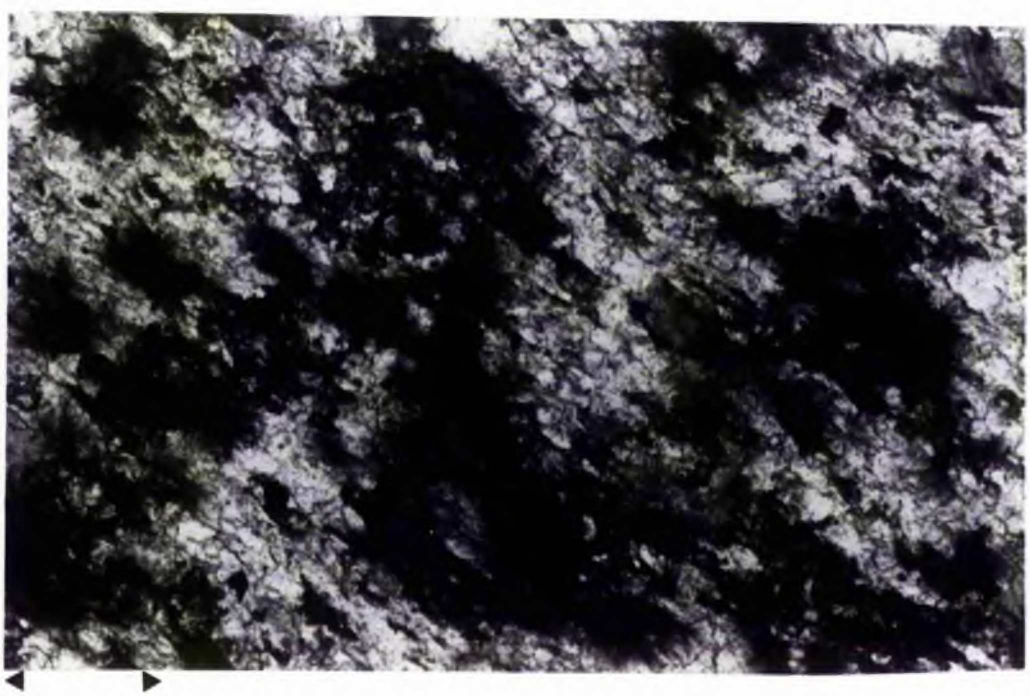












PLATES 17 - 21.

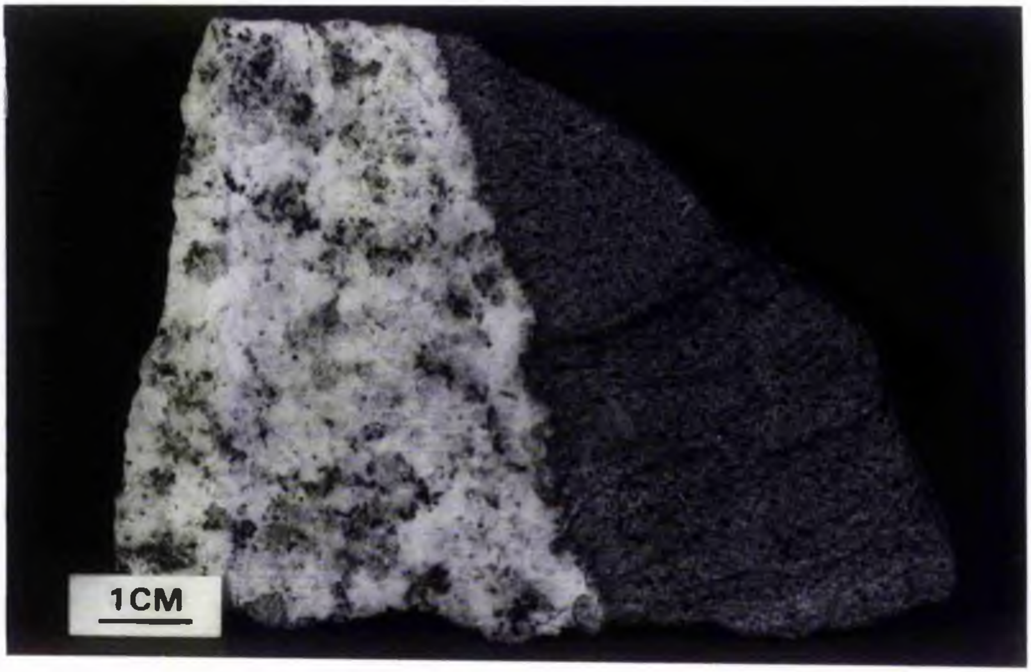
PLATE 17. Top, contact between coarse grained biotite-muscovite granite and biotite hornfels from the Rig of Drumruck, locality 826 (25805649). Bottom, northward dipping contact (arrowed) between biotite hornfels and coarse grained biotite-muscovite granite on Craigdews Hill (24975722).

PLATE 18. Coarse grained biotite granite 73/G. 55-75: top, X.p.l. granulated quartz arrowed, sutured quartz bottom left; bottom, p.p.l., dark mineral = biotite (x 12).

PLATE 19. Coarse grained biotite-muscovite granite 73/G. 54-72: top, X.p.l., bottom p.p.l., dark mineral = biotite, light grey mineral with moderate relief (arrowed) = muscovite (x 12).

PLATE 20. Coarse grained biotite-muscovite granite: top, 73/G. 52-66, vermicular quartz (q) - biotite (b) symplectic intergrowth adjacent to microcline phenocryst (m) (p.p.l., x 40); bottom, 73/G. 53-69, biotite (b) replaced by quartz (q) adjacent to microcline (m), (X.p.l., x 100).

PLATE 21. Coarse grained biotite-muscovite granite: top, 73/G. 60-68, crystalline microperthite developed parallel to the long axis and the Carlsbad twin plane of a microcline phenocryst (X.p.l., x 40); bottom, 73/G. 56-74, secondary muscovite (m) cutting intracrystalline myrmekite (my) within a microcline phenocryst (X.p.l., x 40).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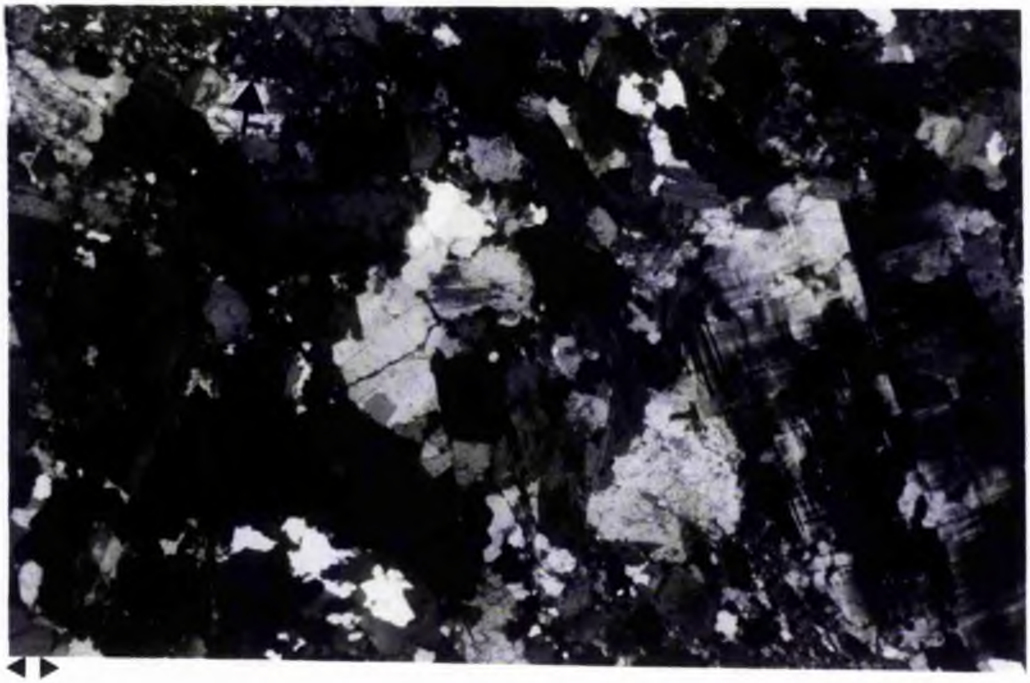
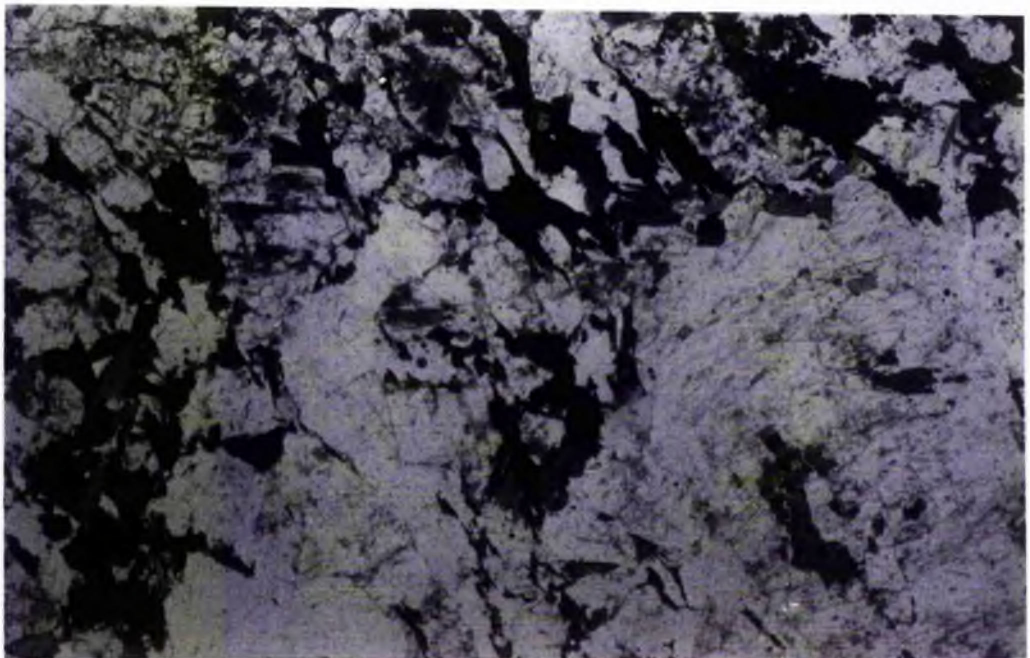
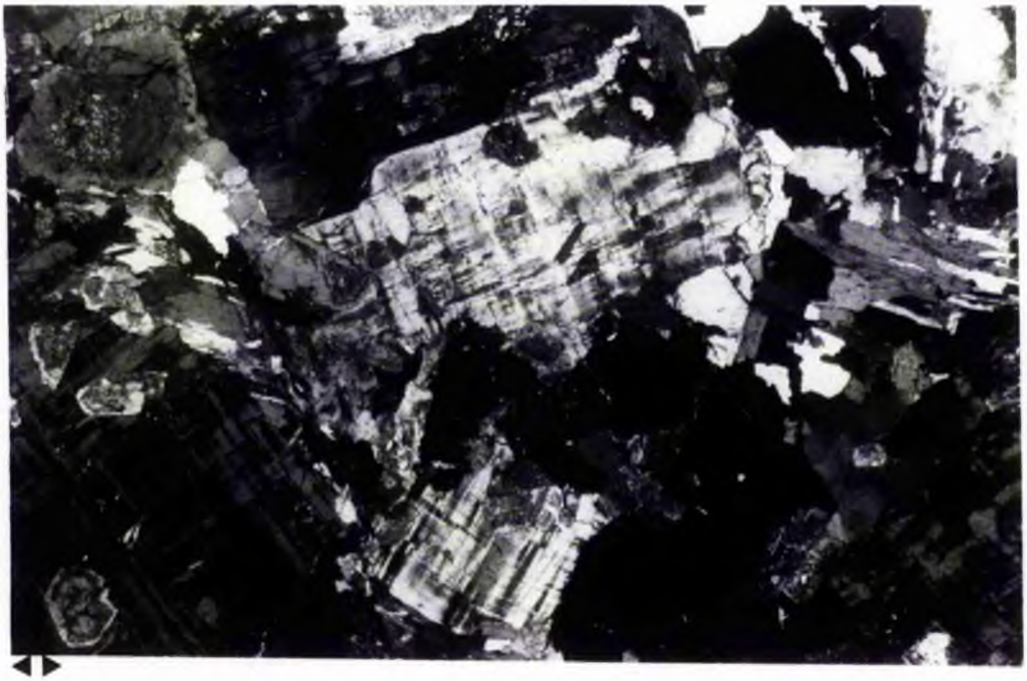
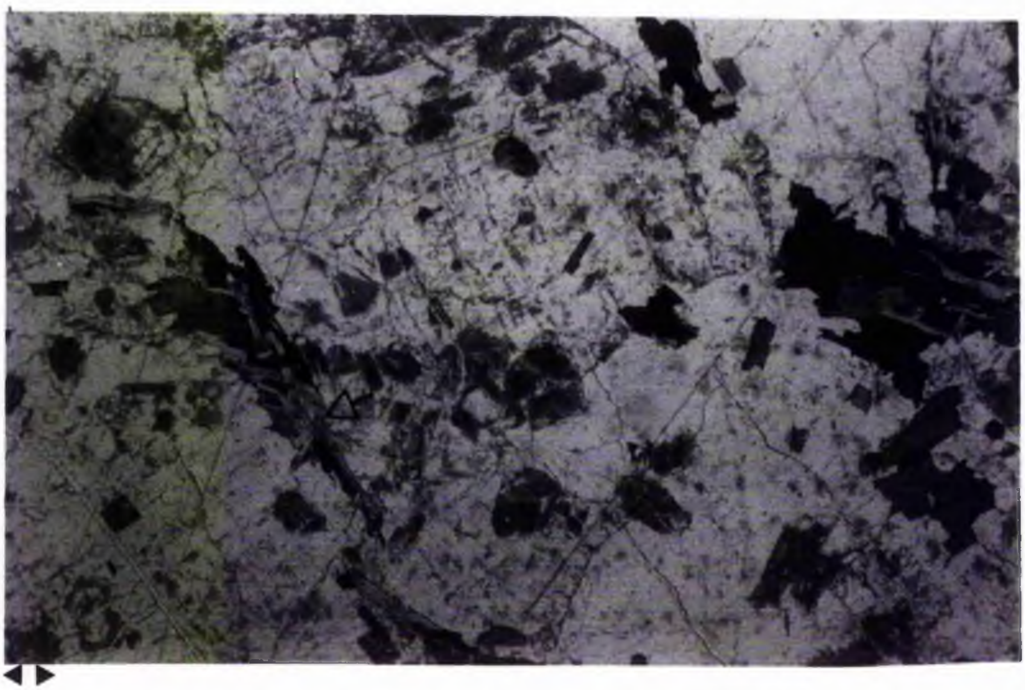
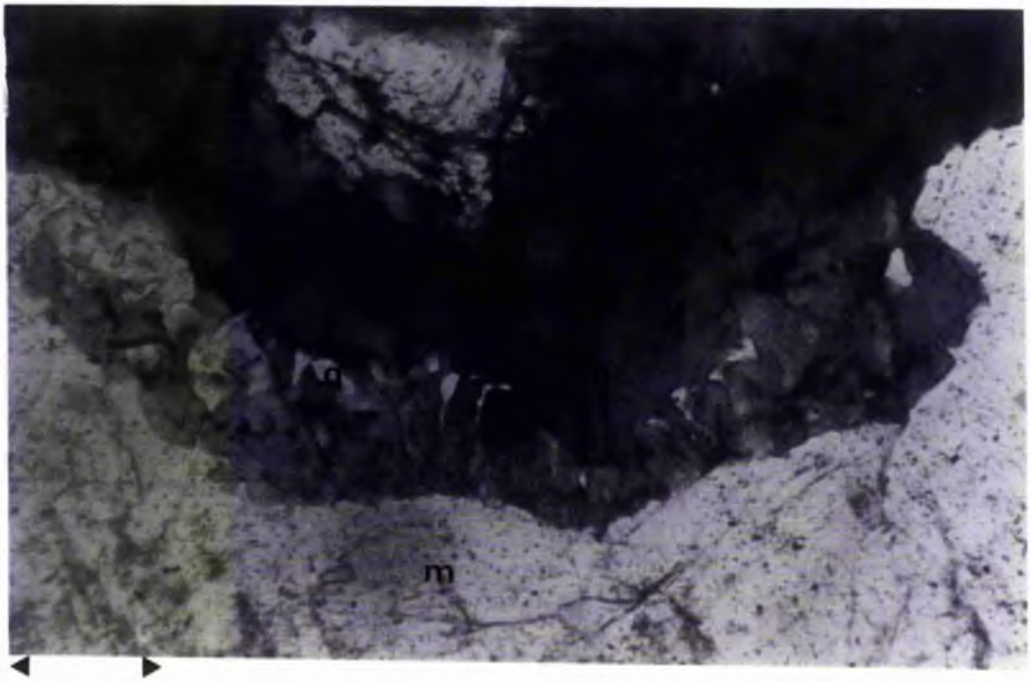
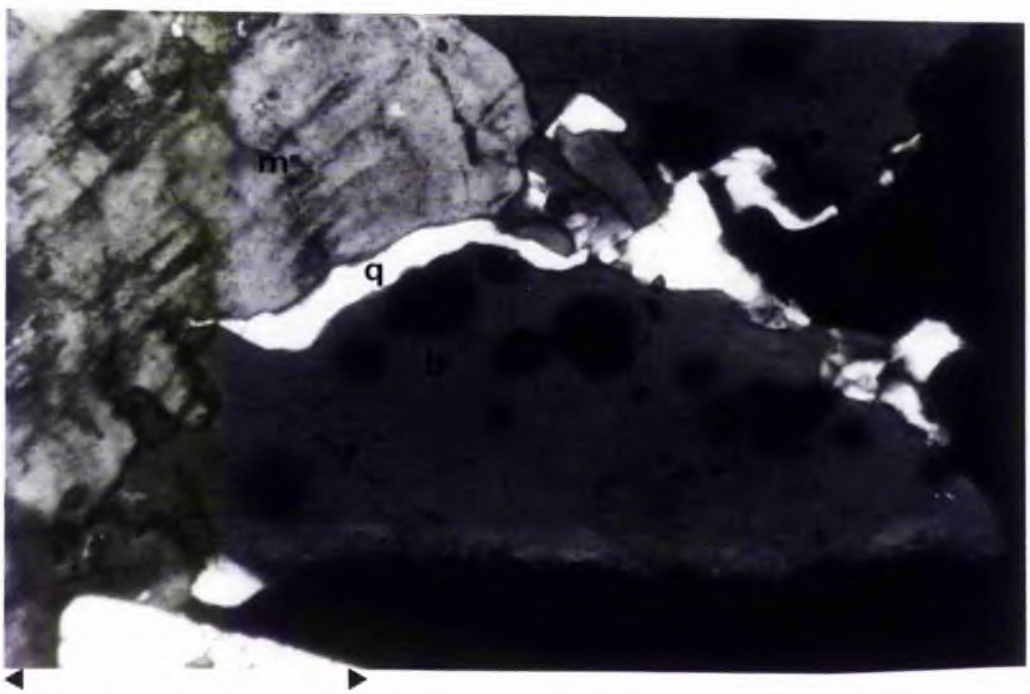


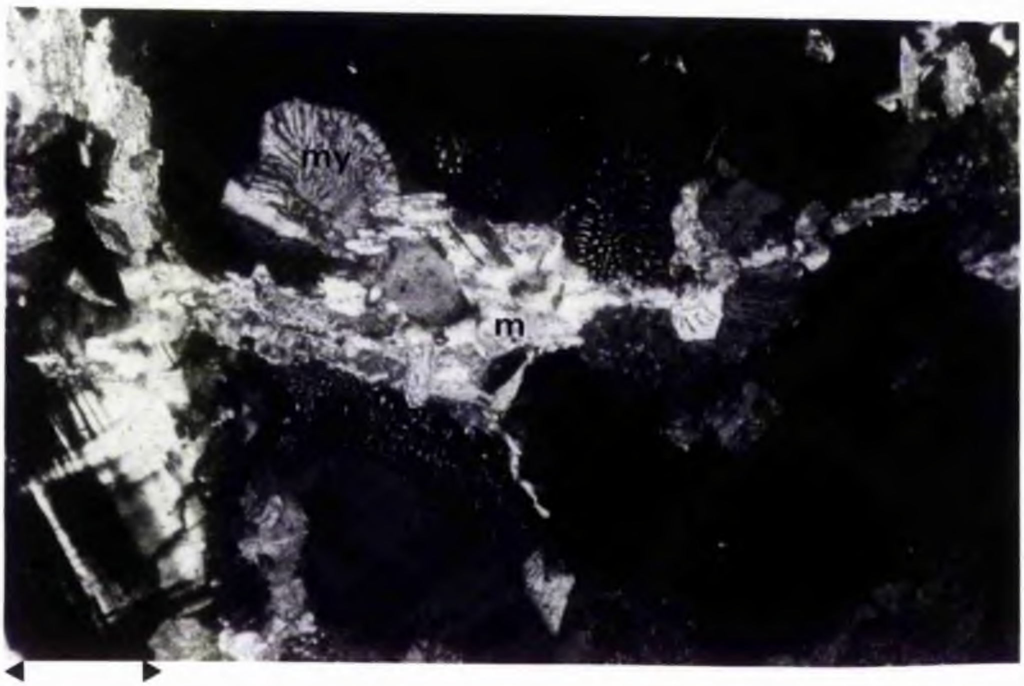







q
m


m
q


my
m

PLATES 22 - 26.

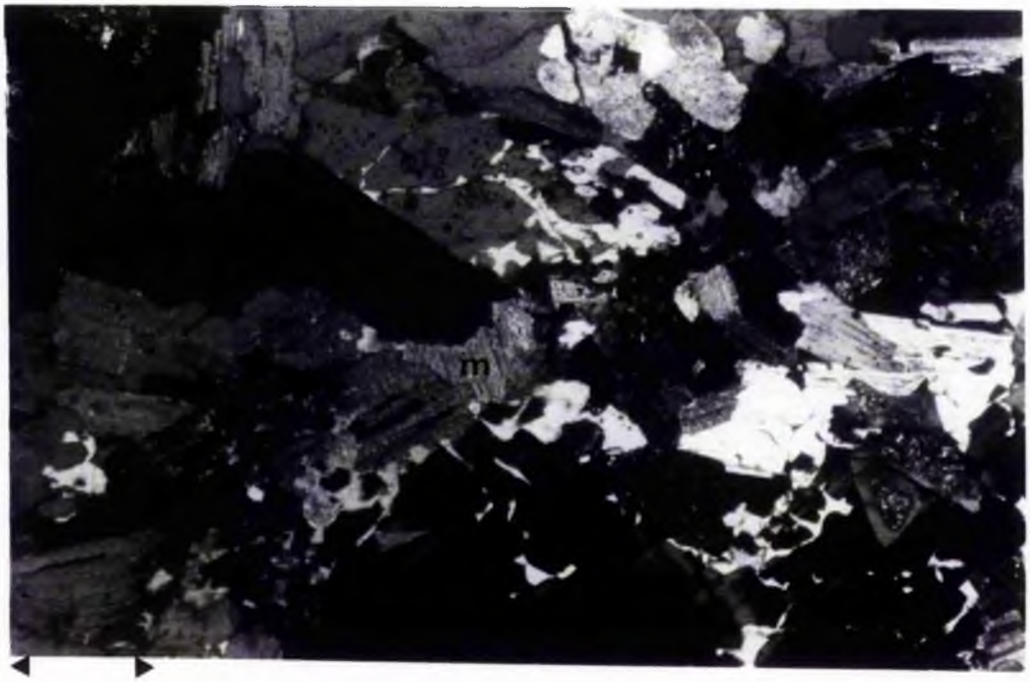
PLATE 22. Coarse grained biotite muscovite granite: top, 73/G. 60-74, replacement of feldspars by quartz (white) and muscovite (m) along a granulation zone (X.p.l., x 40); bottom, 73/G. 61-71, secondary muscovite (m) cutting myrmekite (X.p.l., x 100).

PLATE 23. Coarse grained biotite-muscovite granite: top, 73/G. 60-74, secondary white mica replacing oligoclase along crystallographic planes (X.p.l., x 40); bottom, 73/G. 61-73, biotite (dark) replaced by globular quartz (light grey), (p.p.l., x 40).

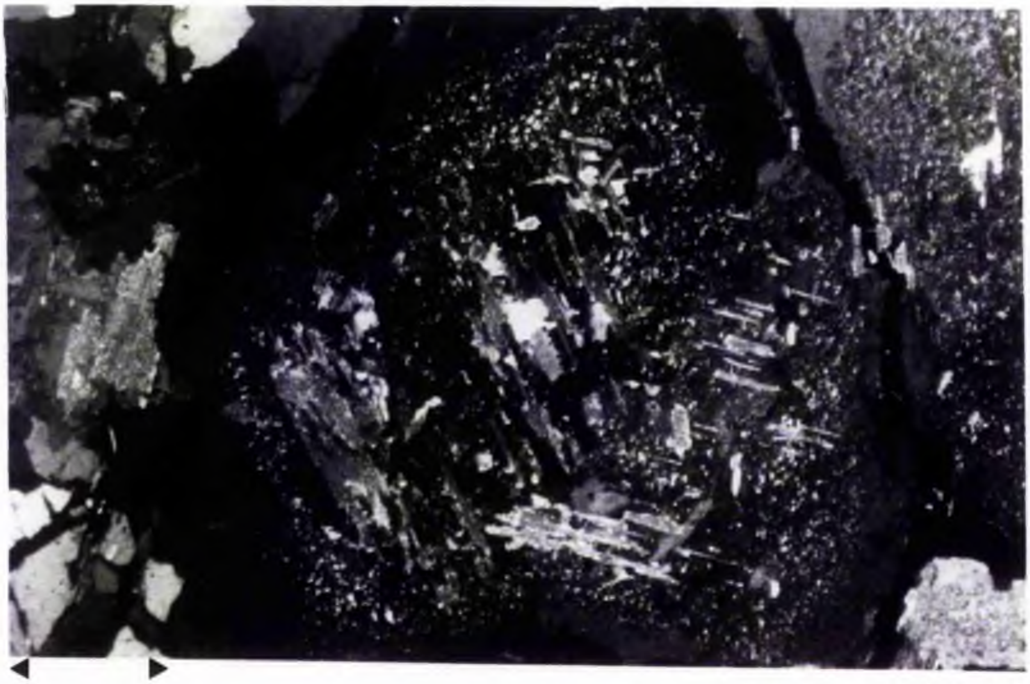
PLATE 24. Coarse grained muscovite-biotite granite 73/G. 54-68: top, X.p.l.; bottom, p.p.l. (biotite arrowed, muscovite = m, x 12).

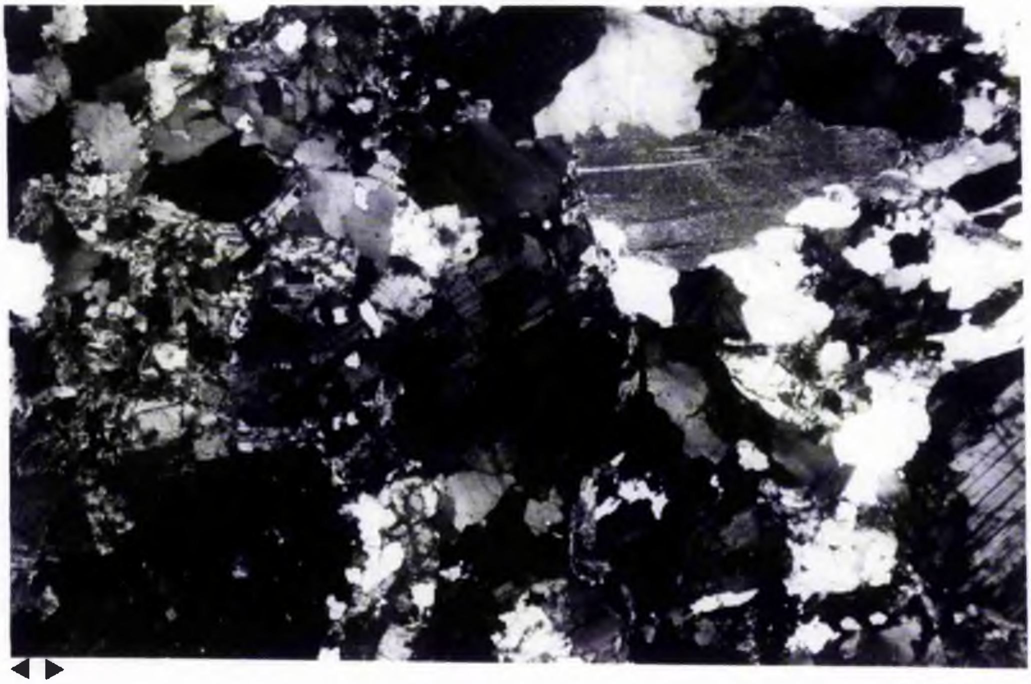
PLATE 25. Fine grained biotite-muscovite granite 73/G. 54-68: top, X.p.l.; bottom, p.p.l. (solid arrow = biotite, open arrow = muscovite, x 12).

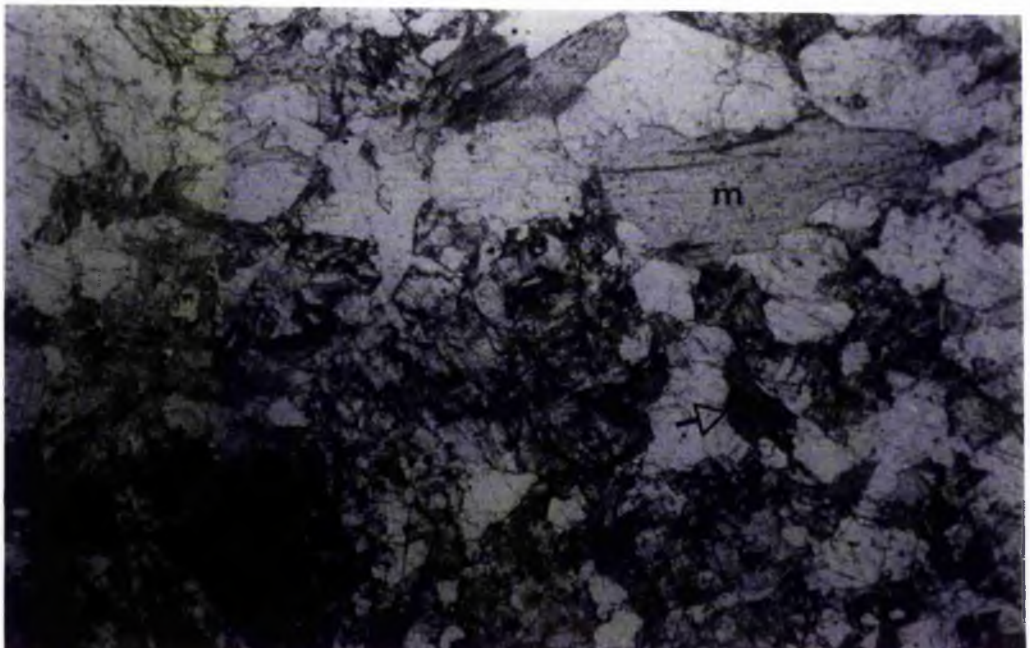
PLATE 26. Fine grained biotite-muscovite granite: top, 73/G. 54-68, micrographic (granophyric) quartz (in extinction) - microcline (m) intergrowth (X.p.l., x 40); bottom, 73/G. 54-70, vermicular quartz-muscovite symplectic intergrowth around the margin of a muscovite crystal (m) adjacent to microcline (mi), quartz (q) and plagioclase (p) (X.p.l., x 100).

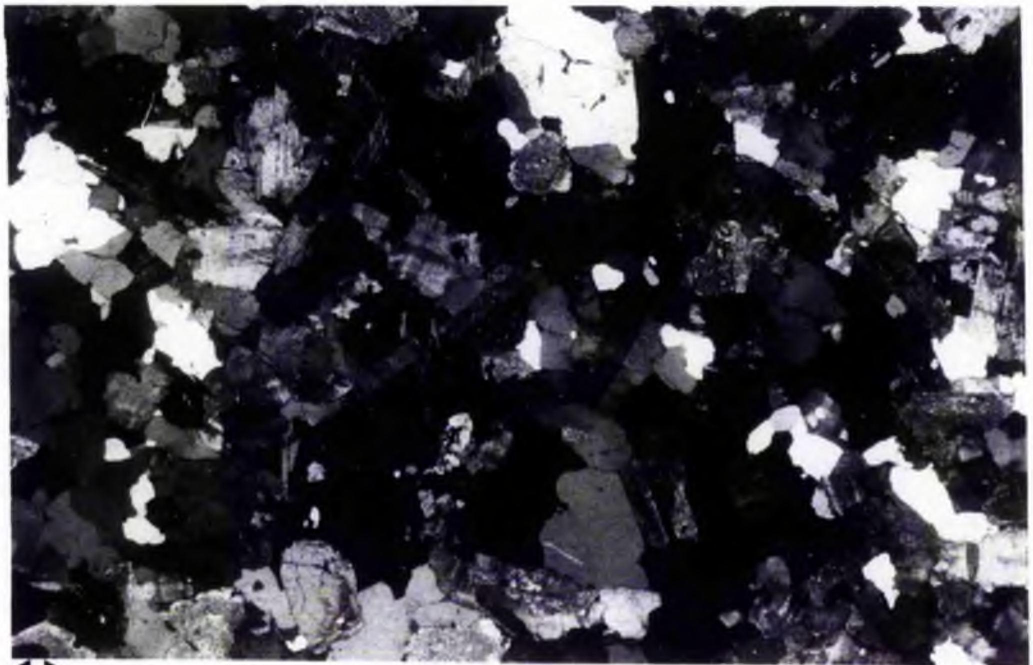

m

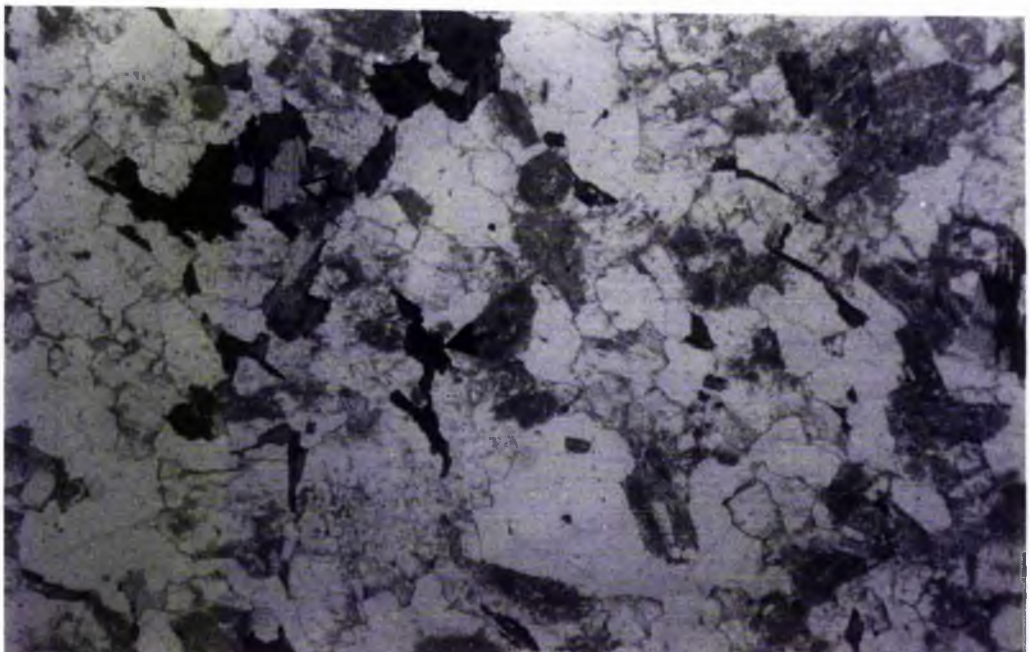

m

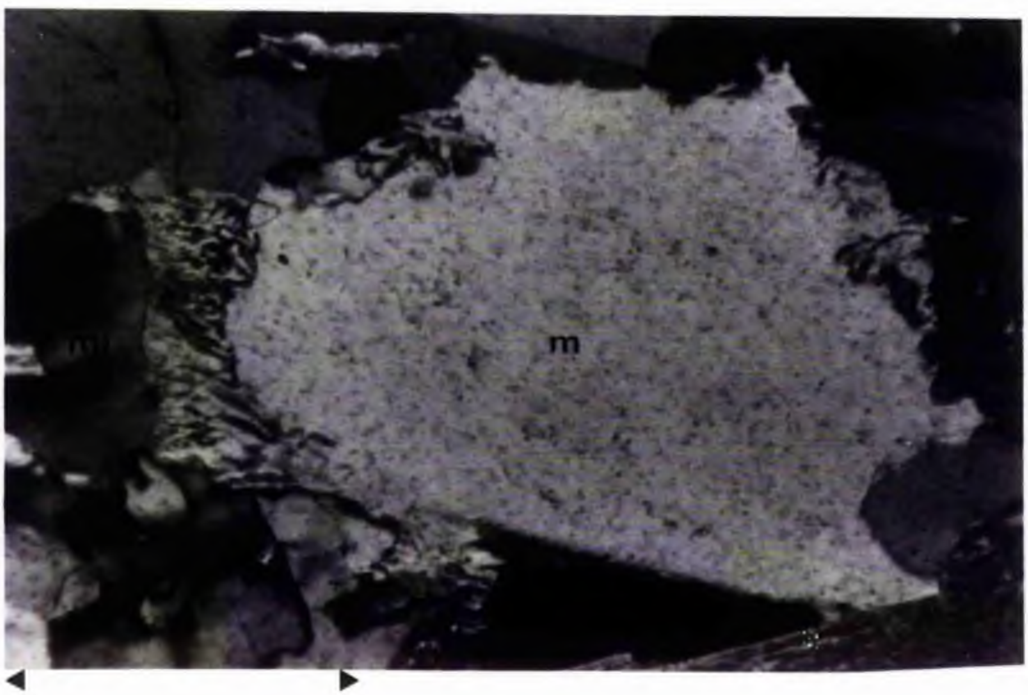





m





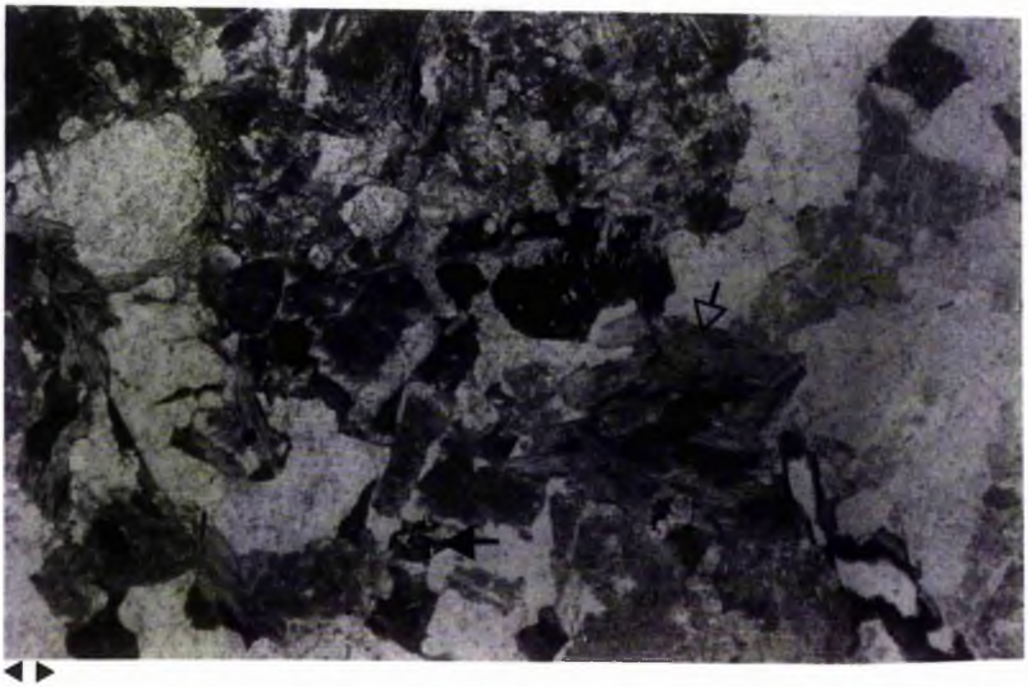

m

PLATES 27-29.

PLATE 27. Fine grained muscovite-biotite granite 73/G. 56-70: top, X.p.l.; bottom, p.p.l. (biotite = solid arrow, muscovite = open arrow, x 12).

PLATE 28. Fine grained muscovite-biotite granite 73/G. 58-70: top, X.p.l.; bottom, p.p.l. (secondary muscovite = open arrow, biotite = solid arrow, x 12).

PLATE 29. Fine grained muscovite granite 73/G. 59-67: top, X.p.l.; bottom, p.p.l. (muscovite = open arrow, garnet = solid arrow, x 12).



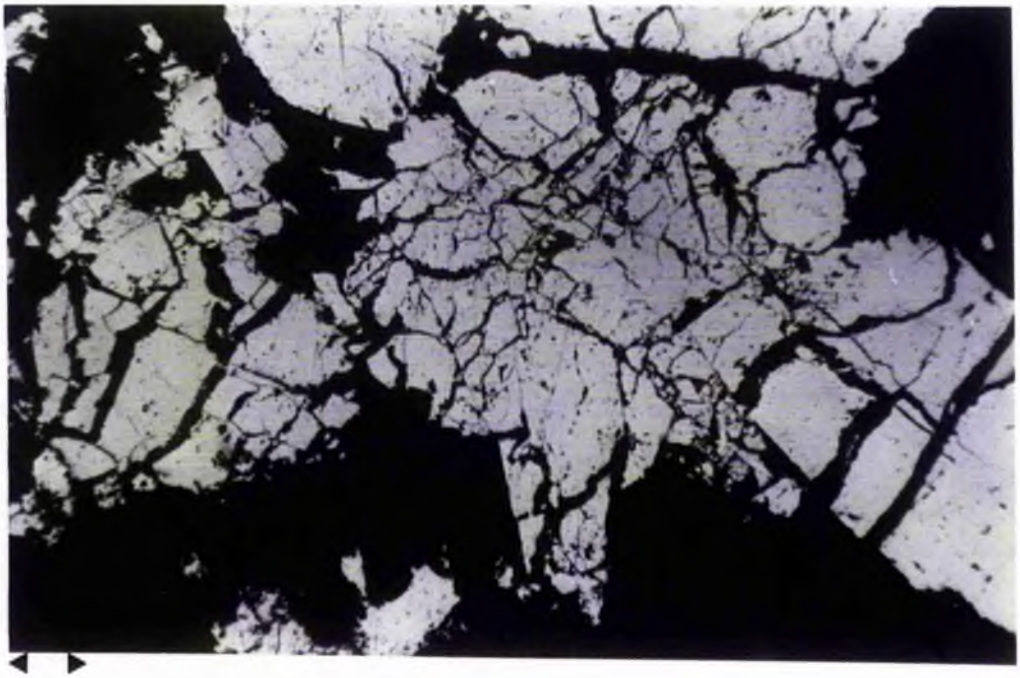
PLATES 30 - 33.

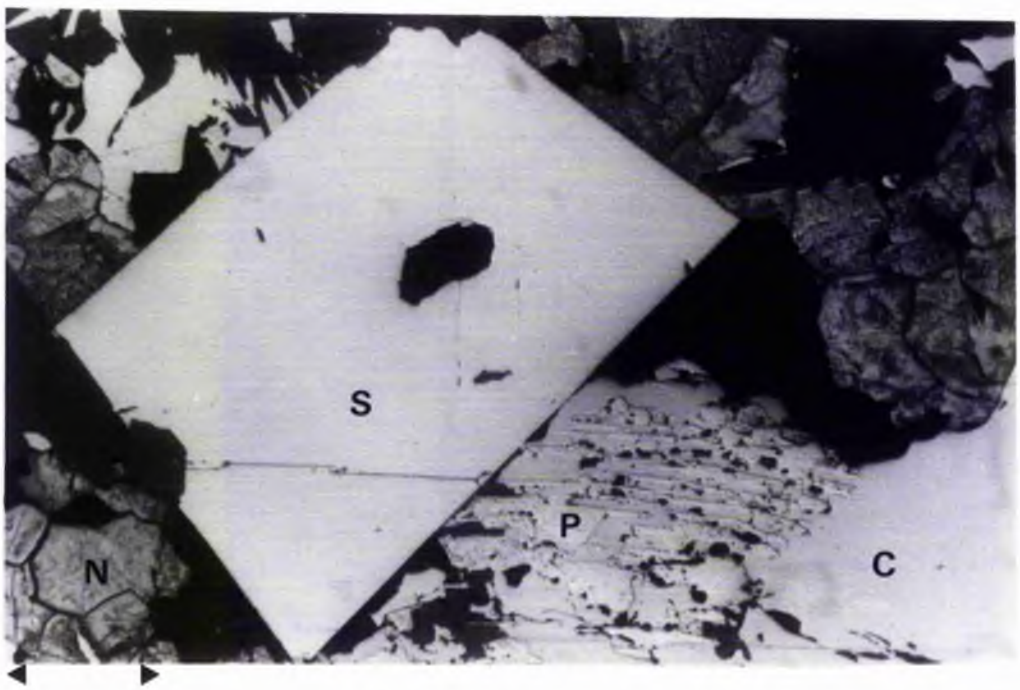
PLATE 30. Top, colloform jasper and silica. Orchars vein (X.p.l., x 40).
Bottom, specular hematite (light grey) in jasper and quartz (dark). Orchars vein (p.p.l., x 40).

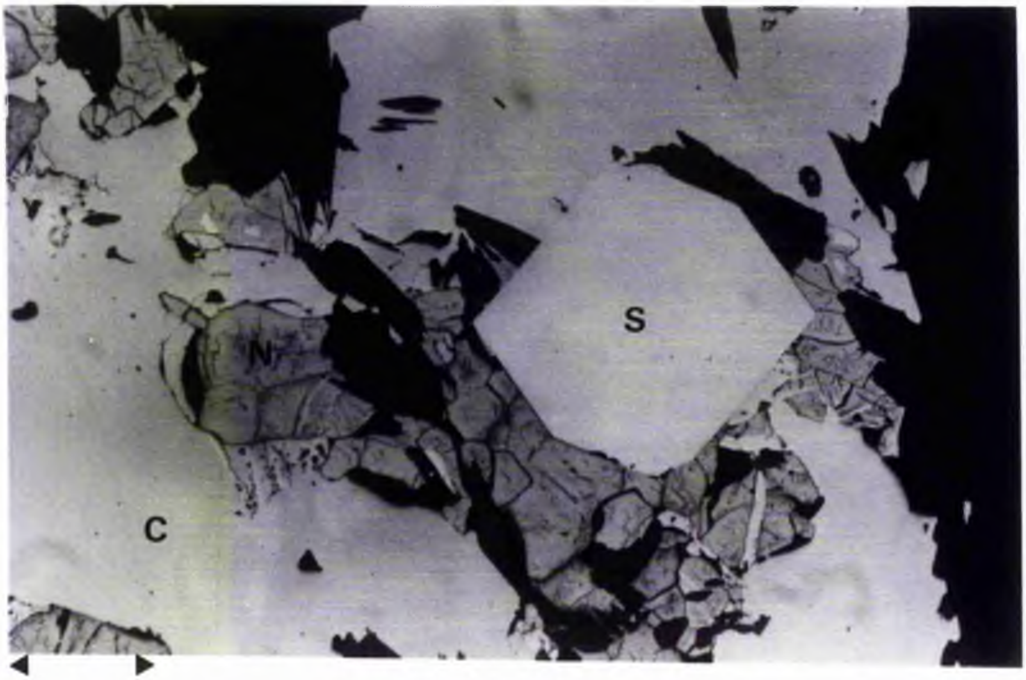
PLATE 31. Top, brecciated arsenopyrite (light grey) in quartz (dark) gangue Palnure Burn, Talnotry, 73/514 (p.p.l., x 20).
Bottom, euhedral smaltite (S) with anhedral niccolite (N) and chalcopyrite (C) replacing pyrite (P) and amphibole (top left) of the silicate gangue (dark). Talnotry, 004D (p.p.l., x 40).

PLATE 32. Top, euhedral smaltite (S) surrounded by anhedral niccolite (N) within chalcopyrite (C) replacing silicate gangue (dark). Talnotry, 004D (p.p.l., x 40).
Bottom, pentlandite (P) enclosed by pyrrhotite (Py) Talnotry, 004 (p.p.l., x 20).

PLATE 33. Top, chalcopyrite (C), enclosing anhedral aggregates of niccolite (N) and replacing biotite (dark) along cleavage. Talnotry, 004D (p.p.l., x 20).
Bottom, chalcopyrite (C) enclosing niccolite (N) and replacing tremolite (dark) along cleavage. Talnotry, 004D (p.p.l., x 20).




S
P
C
N


S
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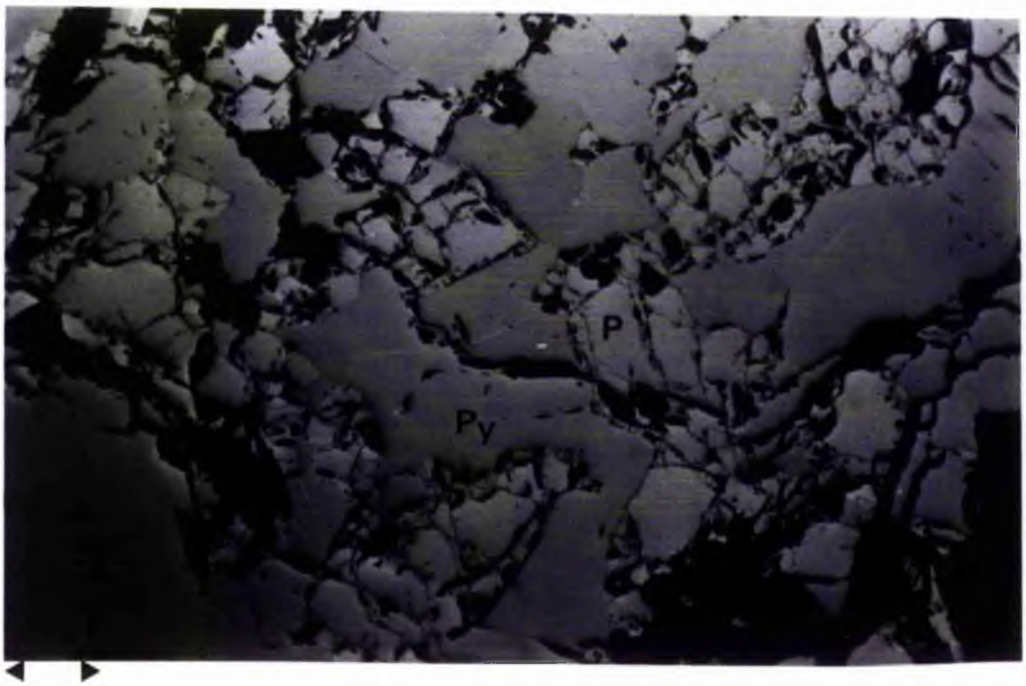
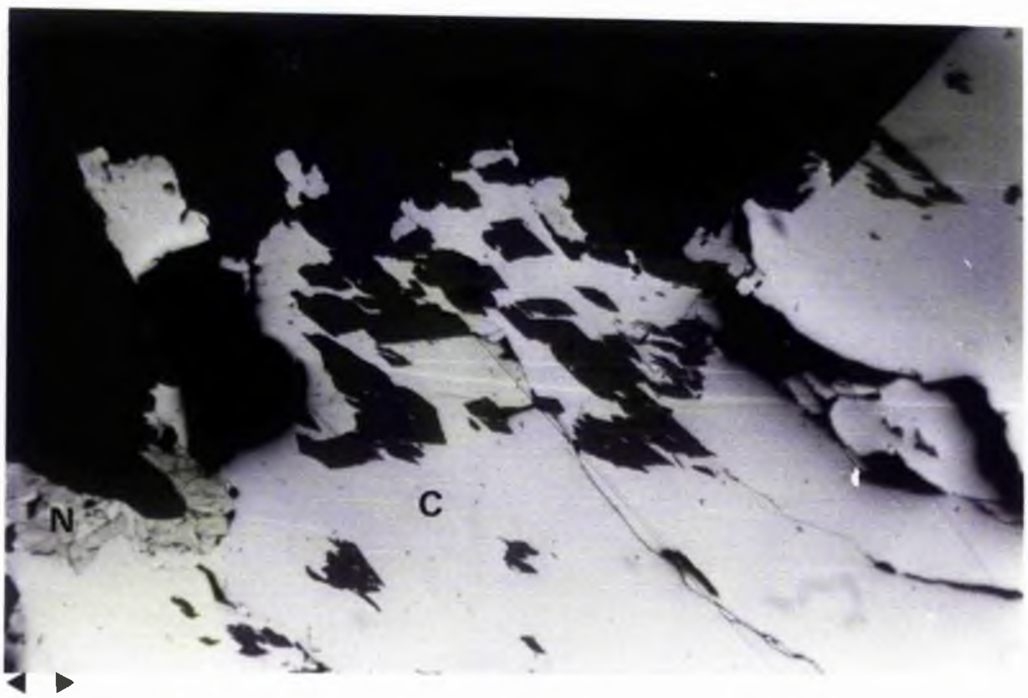

P
Py


C
N


N
C

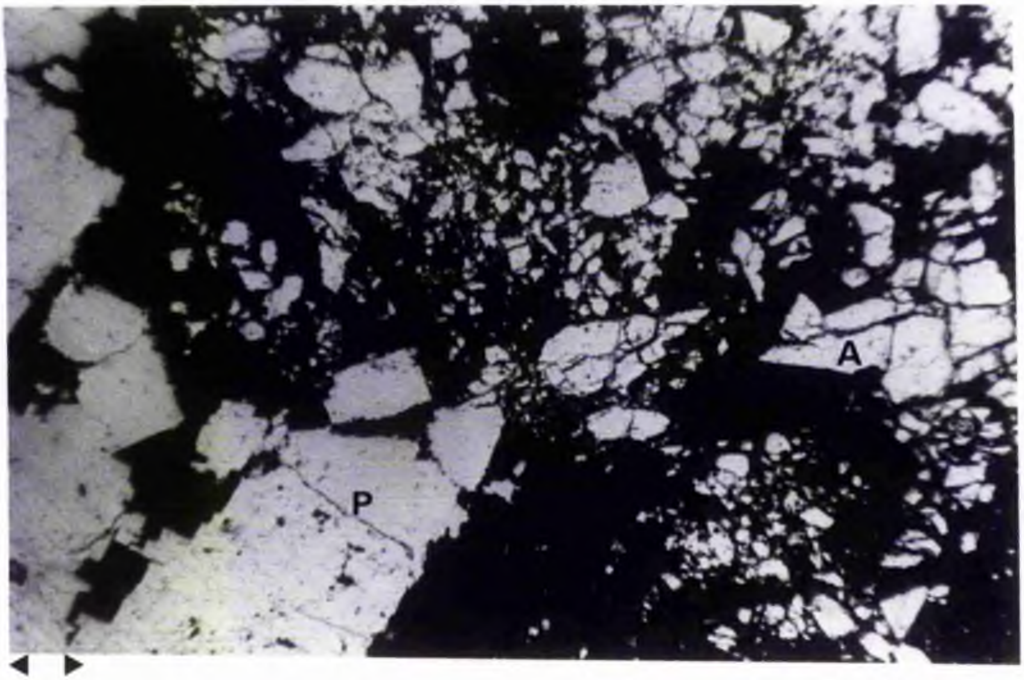
PLATES 34-37.

PLATE 34. Top, pyrite (P) in cubic crystals and arsenopyrite (A) in quartz (dark). Glen of the Bar, Talnotry, 73/515 (p.p.l., x 20).
Bottom, pyrite I (P_1), in subhedral crystals enclosed by polycrystalline and slightly anisotropic pyrite II (P_{11}). Wood of Cree, 73/518A (slightly uncrossed polars, x 40).

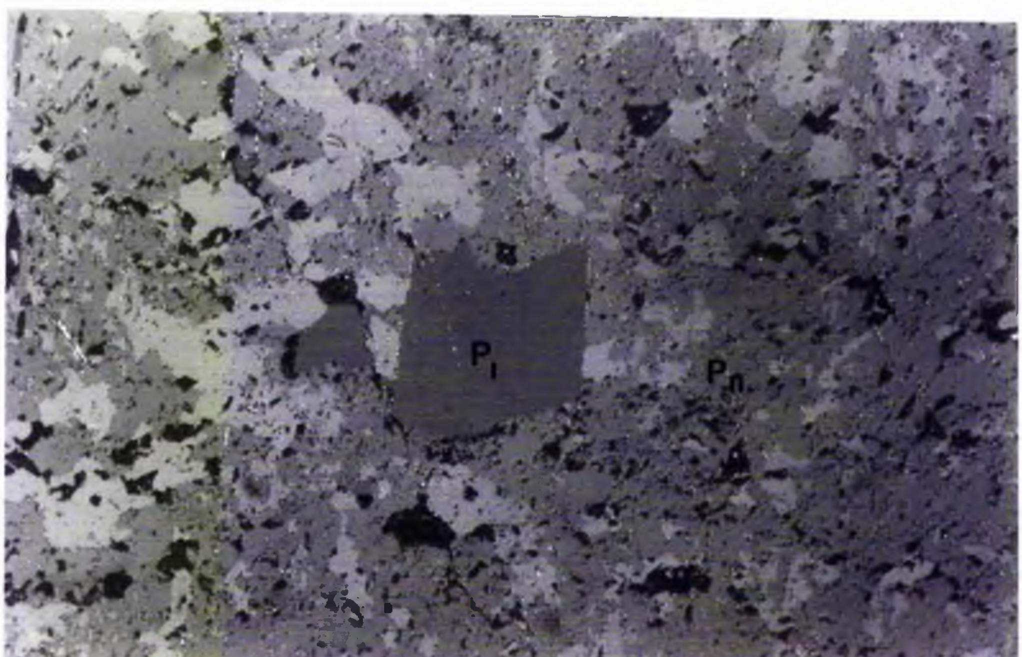
PLATE 35. Top, euhedral pyrite I (P_1) enclosed by galena (G) replacing pyrite II (P_{11}) along 100 cleavage; S = sphalerite. Wood of Cree, 73/518A (p.p.l., x 40).
Bottom, brecciated euhedral pyrite I (P_1) enclosed by galena (G) replacing pyrite II (P_{11}) along 100 cleavage; S = sphalerite. Wood of Cree, 73/518A (p.p.l., x 20).

PLATE 36. Top, extensive replacement of pyrite II (P_{11}) by galena (G) and sphalerite (S). Wood of Cree, 73/518A (p.p.l., x 20).
Bottom, chalcopyrite (C) altered to chalcopyrite and covellite (Ch), and cuprite (Cu) along fractures. Pibble, 74/639 (p.p.l., x 20).

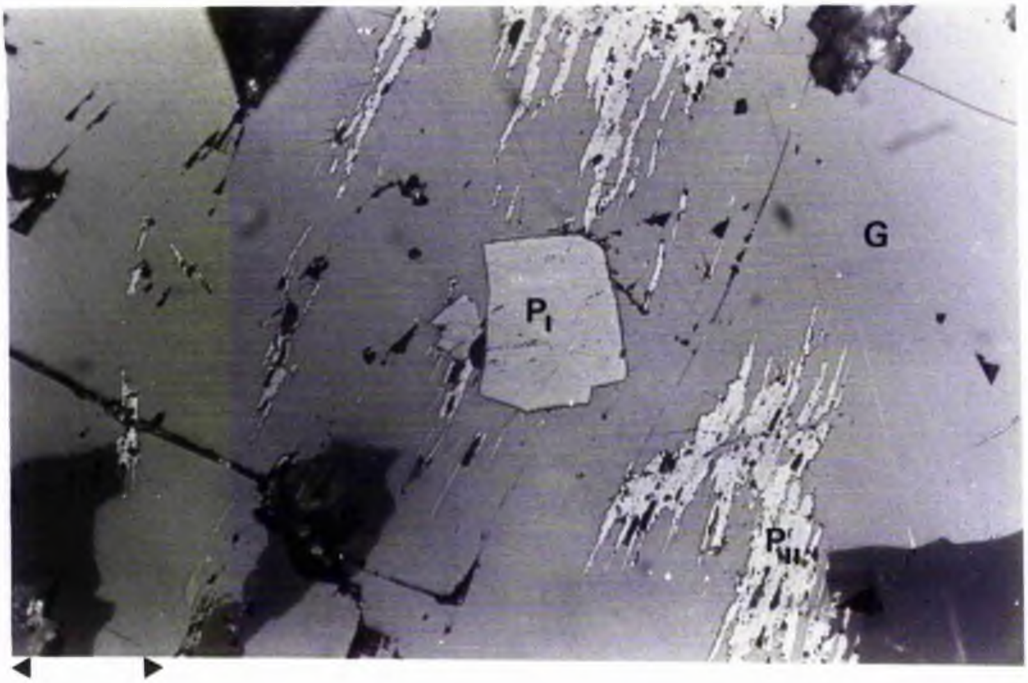
PLATE 37. Top, chalcocite (Ch) replacing and pseudomorphing galena, surrounded by covellite (Co) and cuprite (Cu). Zone of supergene enrichment, Pibble, 74/639 (p.p.l., x 20).
Bottom, native copper (C) and chalcocite (Ch) replaced by cuprite (Cu) along fractures. Zone of supergene enrichment, Pibble, (p.p.l., x 20).

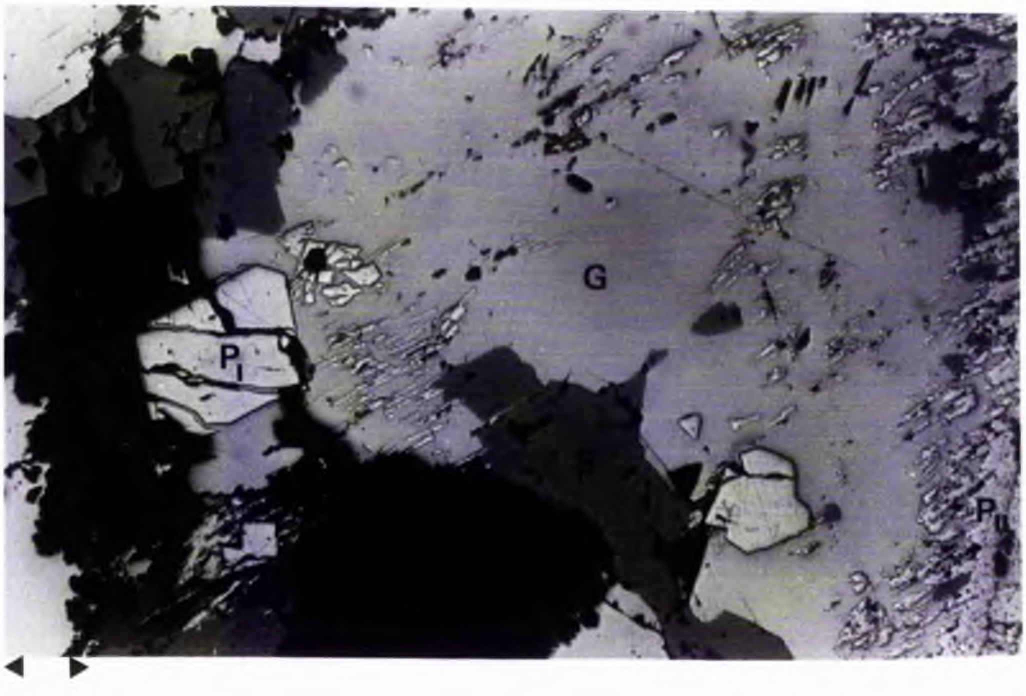


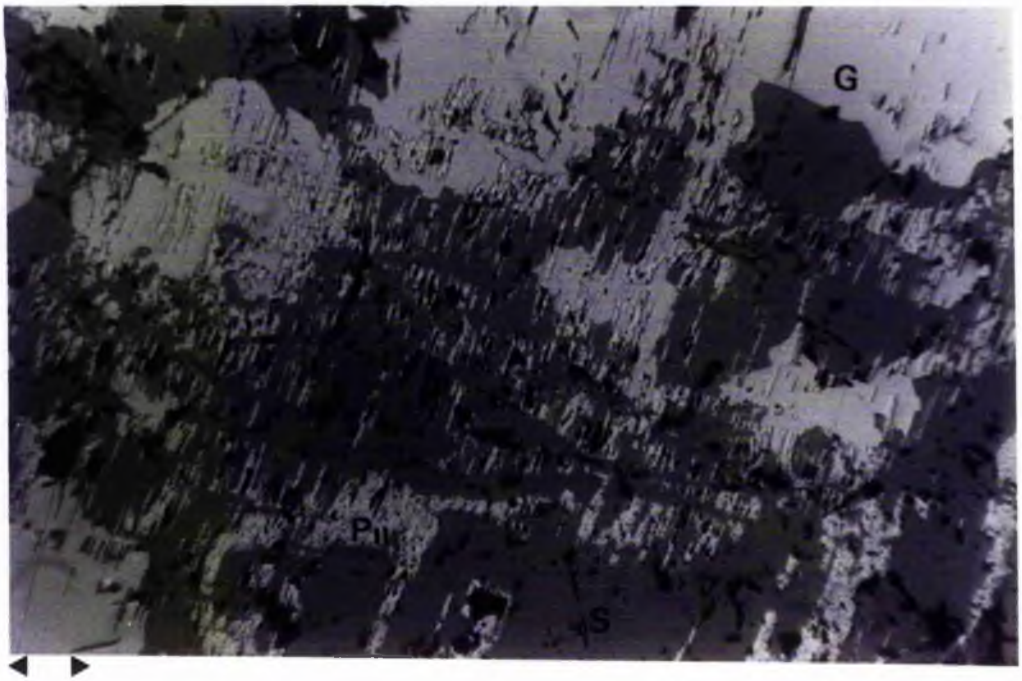
A
P

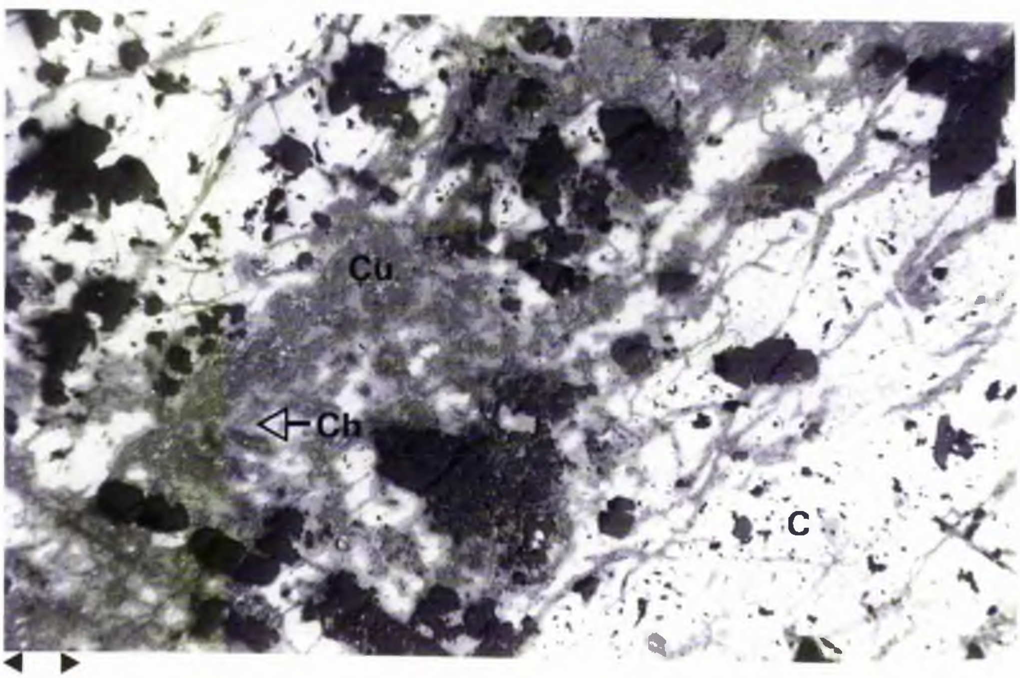


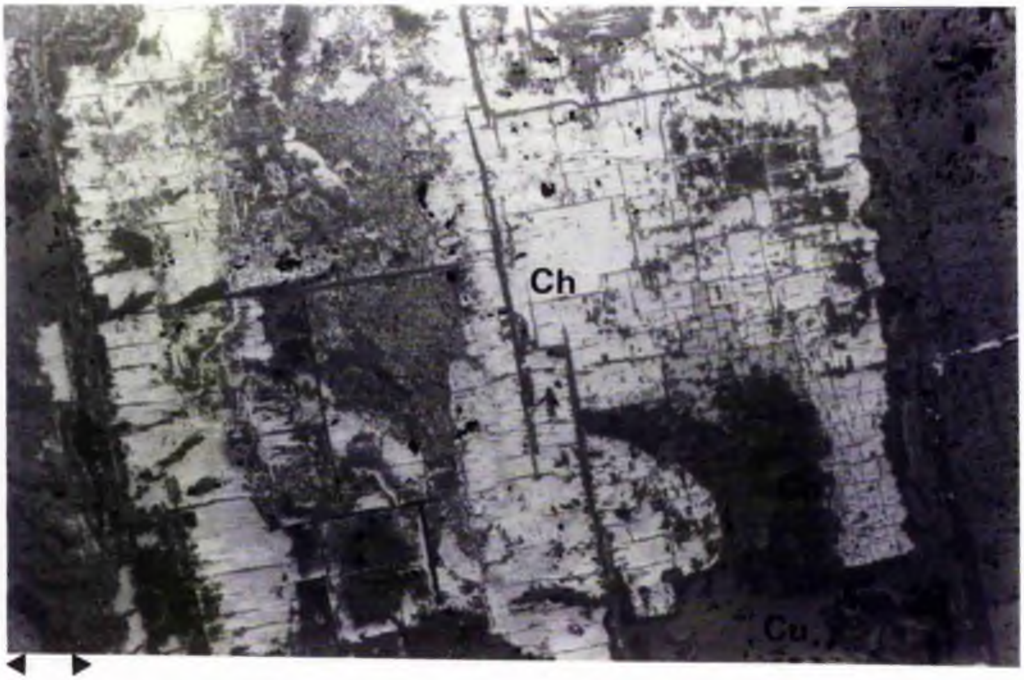
P_I
P_II

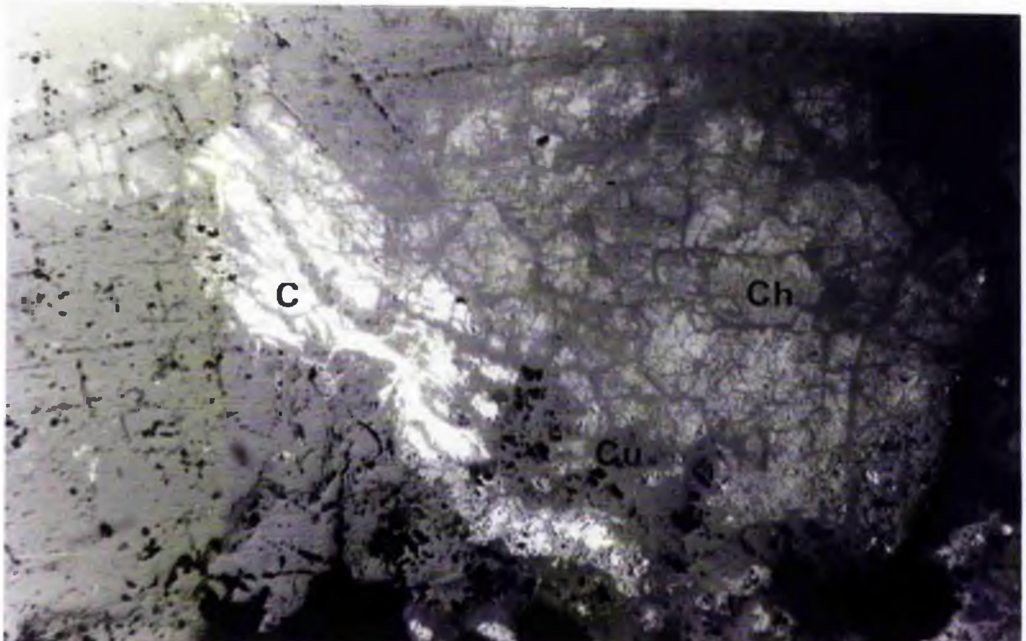

G
P_I


G
P_I
P_{II}


G
Pu
S


Cu
Ch
C


Ch
Cu


C
Ch
Cu

B I B L I O G R A P H Y.

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